# FOREST PRODUCTS JOURNAL

FOREST PRODUCTS RESEARCH SOCIETY

George M. Hunt Receives Hitchcock Award at 15th Annual Meeting

***FEATURED THIS ISSUE →***


**Production with Polyester Finishes**

**Hot-Press Adhesives for Interior Plywood**

**MC of Mechanically Dried Veneers**

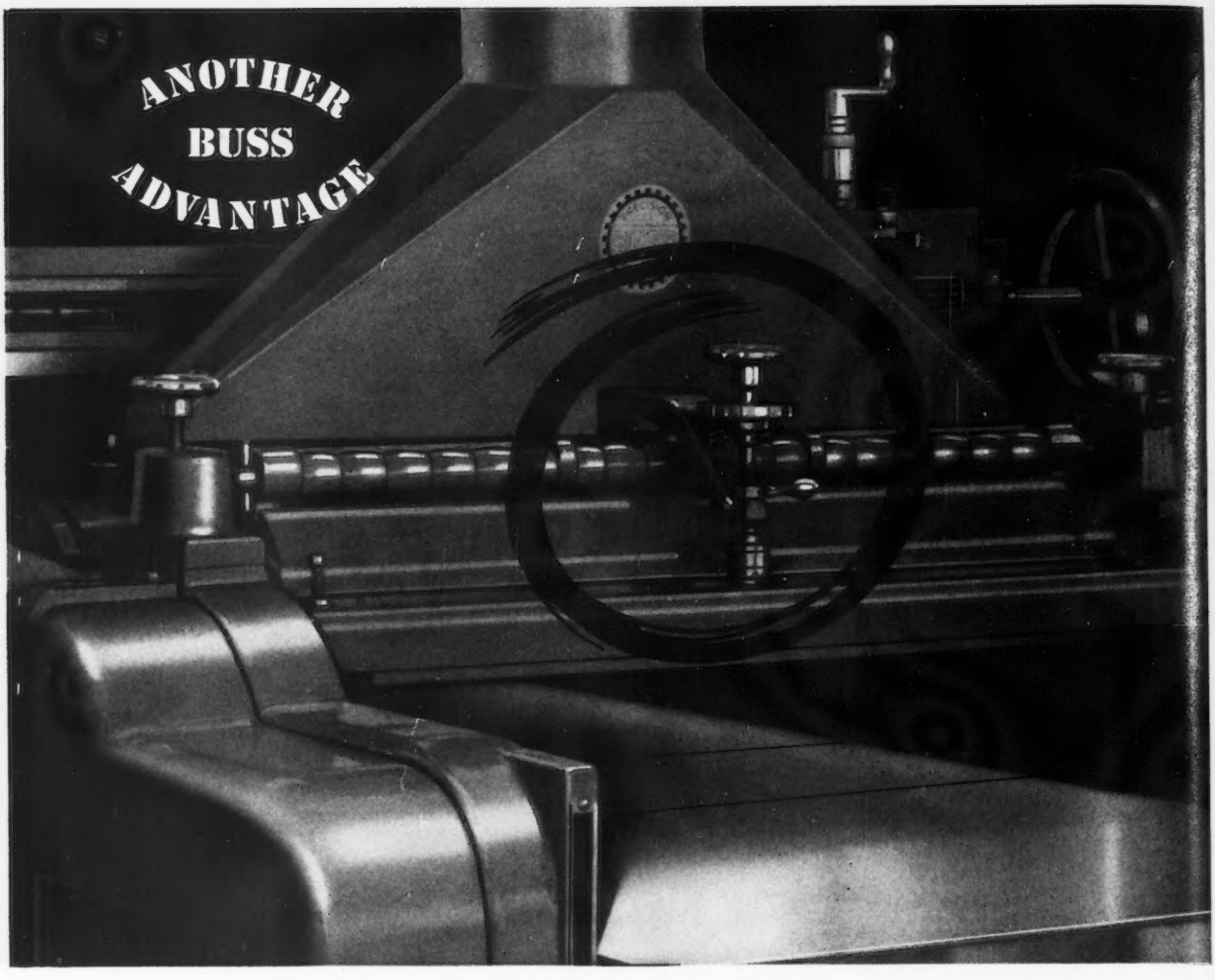
**Lumber by the Pound? Utilization of Residues**

**Microscopic Evaluation of Glue Bonds**

**Economics of Automatic Lumber Sorting**

**How to Relieve Drying Stresses in Veneer**


Vol. XI, No. 7 1961 / JULY

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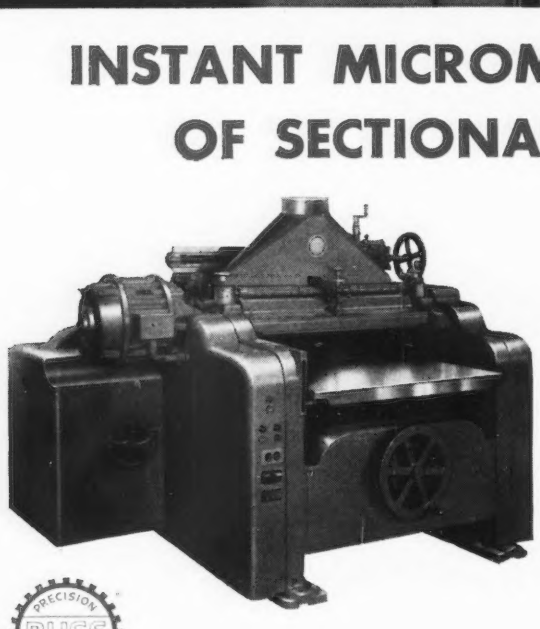

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# . . . from the President's Desk

Donald K. Saunders

THE peculiarities of publishing require that this column be prepared several weeks before its author comes to office. This circumstance may be all to the good; perhaps it will induce a little more soul-searching than otherwise would be the case.

Ray Berry's final column, last month, paid tribute to various individuals, but here it should be emphasized that through his combination of personal interest and conviction, as well as in his capacity as president, he played a leading part in all that he listed.

This transition point makes it proper to follow his final column, which was in the nature of a review, with one again concerned with the future.

The policy report of 1960 described the variety of background and interest of Society members: school administrators, teachers, students; researchers from schools, government agencies, the industry, and supplying industries; administrators and production men from the industry and its suppliers; salesmen; and foresters. Quite likely we shall never cease to be concerned with the problems posed by this diversity. Nevertheless, they should force us to maintain a unique and alert organization.

Our different interests are so obvious that we often forget how much we have in common. To a member concerned chiefly with affairs inside his own geographical area or process field, it is not always clear how much his needs and views toward Society matters are duplicated elsewhere. This community of interest becomes more apparent as his activities spread beyond his customary scope, when he takes part in meetings outside his own section.

The essence of the Society is its members' concern with wood, as a mystery to be explored, a distressingly variable material to be controlled in handling and processing, as one to be strengthened in its position relative to competing materials.

The common characteristic of Society members appears to be dissatisfaction with knowledge, methods, or markets in their present state. This drives us to learn more about what wood is, or what can be done to or with it to make it more reliable in application, or more certainly a means of profitable application.

With these things in mind, the Society's purpose is to collect and to broadcast the various fragments of knowledge and improvements in technique which bear on all the aspects of wood. As the Society has grown, changes have occurred in section and division organizations, in style and emphasis in the conduct of meetings, and in the *Journal*. But all these changes have come about in response to the attempt to carry out the Society's purpose more thoroughly, to exchange information more effectively.

With all that we have done, we still are not doing as good a job as we should. The relatively small number of individuals who can participate frequently in meetings benefit in proportion to their activity. Acquaintances generated at those times enable them further to exchange opinion and information to whatever degree their initiative inspires them.

Various reasons prevent a larger number of members from direct meeting participation. Their needs must be met in other ways, and not only through the *Journal*, which now is our sole agency common to the entire membership.

Our various officers and committees are striving to help the Society change in ways to benefit its members, but their work will be best accomplished with support from a membership which is also willing to contribute, by either meeting participation or contributing ideas to make this an effective Society.

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*With this column, the* Journal *is proud to introduce the 15th President of the Forest Products Research Society, Donald K. Saunders, president and chairman of the board of Saunders Brothers, Westbrook, Maine. Mr. Saunders succeeds Raymond H. Berry of the Scott Lumber Company, Burney, California.*

## 1961 Wood Award Winners Announced at Louisville

LOUISVILLE, KY., Monday, June 19 —At the first general session of the Forest Products Research Society's Annual Meeting here, Robert H. Kunesh, University of Michigan, and Richard Mark, Yale University, were granted cash awards and certificates of merit as winners of the 12th Annual Wood Award Competition.

Kunesh

Mark

The awards were presented by J. F. Koellisch, editor and publisher of *Wood and Wood Products Magazine,* which sponsors the competition in cooperation with the Society.

Robert H. Kunesh received the first place $350 award and certificate for his paper entitled "The Inelastic Behavior of Wood: A New Concept For Improved Panel Forming Processes," which was a condensation of a thesis for the degree of master of wood technology at the University of Michigan in August, 1960.

Kunesh is now employed as a technologist at the Research Division, Seattle Branch, Weyerhaeuser Co., Seattle, Wash. His paper was submitted by N. C. Franz, associate professor in the Department of Wood Technology at Michigan.

Second-place winner, Richard Mark, received $150 and a certificate of merit for his work on "Wood-Aluminum Beams Within and Beyond the Elastic Range, I. Rectangular Sections." Currently a candidate for the degree of doctor of forestry at Yale, Mark formerly specialized in product development for Balsa Ecuador Lumber Corp., New York, N. Y. His paper was submitted by F. F. Wangaard, professor of lumbering, Yale University.

In announcing the awards, Koellisch paid tribute to Dr. Harry Troxell, Colorado State University; Dr. Hereford Garland, Michigan College of Mining & Technology; and Prof. Boyd Richards, Auburn University, who served as judges.

Koellisch also reported that he is working with Eric Anderson and Everett Ellis, co-chairmen of the FPRS Education Committee, on plans for the 1962 awards, which will be announced early this fall.

*FROM THE COVER*

# G. M. Hunt Honored for "Lifetime Service"

LOUISVILLE, KY., Monday, June 19.—The dean of the wood researchers, and one of the 14 men who met in Madison 15 years ago to found the Forest Products Research Society, was honored here today when George M. Hunt was granted the first Hitchcock Award.

In presenting the award, V. C. Hogren, executive vice president of the Hitchcock Publishing Company, read the following statement from Dr. E. S. Harrar, chairman of the Hitchcock Award Committee:

"Mr. Hunt's selection was based on his having given himself unselfishly for a lifetime of service in the public interest, with many contributions in research to the wood products industry. He has been a leader in urging the full and proper use of wood. His successful administration of the U.S. Forest Laboratory at Madison, Wisconsin, established a symbol for those in public service. His love of research, his personal sacrifices over the years as a public servant, and the broad impact of his contributions also were instrumental in his being selected."

A graduate of the University of California, Hunt devoted 40 years to service in the public interest. He joined the U. S. Forest Service in 1911 at San Francisco. Two years later he transferred to the Forest Products Laboratory at Madison, as a chemist in wood preservation.

In 1919, he was appointed chief of the Division of Wood Preservation, a position he held until 1944 when he became assistant director of the Laboratory. Through his research at the Laboratory, his industrial studies in this country and Europe, and his writings and reports, he was soon recognized both here and abroad as an authority on wood preservation, fireproofing, glued laminated construction, glues and plywoods, and wood finishes. He is the author of numerous technical publications and co-author of the well-known text, "Wood Preservation."

He was named director of the Laboratory March 1, 1946, and he held this post until he retired in March 1951.

It was also in 1946 that Hunt, in cooperation with other research and industrial leaders, stimulated recognition of the need for a society to serve as a clearing house of forest products research and development.

A conference held at the U. S. Forest Products Laboratory in March 1946, was attended by 88 representatives from states, universities and the U. S. Forest Service. At this conference, Bror L. Grondal, University of Washington, presented a proposed constitution for a forest products research society and asked that the group endorse formation of such a society with an invitation to industrial groups to join. An organization committee was found to include industrial representation. This group—14 men in all —met January 3, 1947 to formally establish the Forest Products Research Society.

Later Grondal, a member of the first executive board, stated: "If anyone deserves credit for organizing the Society, it was George Hunt. He got behind the idea and really pushed it."

Since its inception, Hunt has been a firm believer in and a strong proponent for FPRS. He has maintained his interest, and he has constantly attempted to "keep in touch," no matter where his professional duties led him.

Shortly after he retired from the directorship of the Laboratory, Hunt served as special consultant and liaison officer for several governments. In 1954, he was invited to act as a special advisor at the Philippine Forest Products Research Institute. He recently became the first visiting American scientist to receive the outstanding achievement award of the National Research Council of the Philippines, top scientific body of that country.

The award was granted for his studies on utilization of forest products and for distinguished service in the establishment and development of the Research Institute. He recently completed almost 7 years of duty at the Institute and returned to Madison.

In another recent honor, Hunt was awarded the 50th Anniversary Distinguished Service Medal by the New York State University, College of Forestry for "inspiring guidance in forest products research."

The Forest Products Research Society and the Hitchcock Publishing Company are proud that the first in this series of awards has gone to such a distinguished recipient.

## SECTIONS *in the NEWS*

### Helicopter Logging Tests Described at PNW Meeting

"High-lift helicopters will be tested for logging in Oregon this fall," stated Glenn Jackson, California–Oregon Power Co., at a meeting of the Pacific Northwest Section in Medford, Oregon, May 8–9.

Helicopter performance was shown by movies of logs, mortars, and trucks being transported. The prototype craft have a capacity of 8 tons with piston engines and 12 tons with gas turbines. The helicopters will be used to remove logs and trees from areas where conventional methods are prohibitive. Cost of transporting logs 2 miles to a truck road would be comparable to present costs, Jackson said.

#### Technical Sessions

D. J. Miller, Oregon Forest Research Center, described tests comparing eight Oregon woods with Douglas-fir for use as crossties. More than 10,000 ties are involved, and preliminary inspections indicate several species not now popular may serve well as crossties.

Carl Rasmussen, Western Pine Association, described tests of papers and films for use as protective covers for lumber in storage.

Standards for timber quality were discussed by C. A. Newport, Pacific Northwest Forest and Range Experiment Station, who pointed out that log-grade rules for ponderosa pine will be valuable if they correlate with volumes of the grades of products that can be produced.

F. C. Ratliff, Crown Zellerbach Corp., reported that turpentine and tall oil can be recovered profitably in pulping operations with western conifers, and that their removal lessens foaming problems.

G. F. Hoerber and Lawrence Leney, Institute of Forest Products, Seattle, described projects on veneer research. Hoerber reported on thickness variations in Douglas-fir veneer, and Leney presented moving pictures of the veneer process taken through a microscope.

In other papers, B. F. Cooper, School of Pharmacy, Oregon State College, described the use of wood flour in pharmaceutical tablets; and R. W. Kennedy, University of British Columbia, reported on the influence of density, growth rate, and fibril angle on microtensile strength of Douglas-fir.

**MIDWEST STUDENT AWARDS: Student memberships were recently presented to Eugene McAdams, Thomas Nash, and Charles Costeel, students at the School of Forestry, University of Missouri. Sponsored by FPRS Midwest Section, the awards were presented by R. H. Westveld, director of the School of Forestry.**

### Furniture Production Clinic

A One-Day Furniture Production Clinic, attended by 125 men, was held by the Northeastern Section of FPRS and the Jamestown Area Furniture Manufacturers Association, at the Jamestown Hotel, Jamestown, New York on Monday, May 15, 4:00 to 10:00 P. M.

The following formal papers were presented before dinner:

*"The Production and Use of Dimension Stock,"* Wendell W. McMillen, Pres., McMillen Lumber Products Co., Sheffield, Pa.

*"Theory and Practice of Predrying,"* Joseph LaSpisa, Moore Dry Kiln Co., Jacksonville, Fla.

*"Particle Board and its Use in Industry,"* Robert K. Hudson, Dist. Mgr., Formica Corp., Buffalo, N. Y.

*"HiFrequency Gluing Techniques,"* Paul D. Zottu, Pres., Industron Corp., Newton Highland, Mass.

After dinner, work shops were conducted by a panel of experts as follows: "Dimension Stock Production and Use" (J. Edgar Dennedy, Hardwod Dimension Manufacturers Assn., Bruce Burns, Burns, Burns Case Goods Corp., Louis J. Bosse, Jamestown Furniture Mart, T. K. Creal II, Cherry Grove Lumber Co.); "Pre-Drying Theory and Practice" (Joseph LaSpisa, Moore Dry Kiln Co., Wendell McMillen, McMillen Lumber Products Co., William Reed, Imrie Dry Kiln Representative, Lee Peterson, Jamestown Sterling Corp.); "Particle Board Use in Industry" (Richard Putnam, Borden Co., Kermit Forsgren, Crescent Furniture Co., Andy Jochum, Jamestown Veneer & Plywood Corp., Eugene Van, Fancher Furniture Co., and Robert K. Hudson, Formica Corp.); and "High Frequency Gluing Techniques" (Paul D. Zottu, Industron Corp., Maynard Atkins, Electronic Service, Harold Kratzert, High Frequency Service, Ed Haines, Jamestown Lounge Co.).

One of the outstanding features of the meeting was the honor paid to industrial arts instructors and two outstanding students from each of seven high schools located in the Jamestown area. The students and their instructors attended the meeting and after dinner, a special seminar was conducted for them by Professor Harold Core, Dr. Carl deZeeuw and Dr. Eric A. Anderson of the Wood Products Engineering Department of the State University College of Forestry. It is hoped that action of this type will stimulate interest in the wood industry and possibly result in instituting some instruction in wood in the industrial arts curriculum of the high schools.

### New Laboratory for Oregon State

Oregon will have the beginning of what could become the nation's leading forest research center when the first unit of a new $1,500,000 Forest Insect and Disease Laboratory is completed at Oregon State University.

This new federally operated laboratory will join other forest research facilities already at Oregon State. On campus now is the forest research division of the Agricultural Experiment Station. The Oregon Forest Research Center will officially become a part of the experiment station and the campus in July and will be known as the Oregon Forest Laboratory.

Some 25 persons will be employed to do basic research on forest insects, forest diseases and plant physiology when the first unit of the federal laboratory is completed. It will be operated by the Pacific Northwest Forest and Range Experiment Station, Portland, Ore.

Basic research undertaken at the forest insect and disease laboratory includes nature and cause of disease resistance in trees, physiological cause of decline in tree growth and vigor, and biological control by insect parasites and predators. Although the federal laboratory will concern itself with basic research, the OSU-operated Oregon Forest Laboratory will emphasize applied research.

**MEMBERS AND GUESTS of the Great Lakes Section observed production of household wraps at Dow Chemical Co. plant in Midland.**

OFFICERS AND SPEAKERS at the annual meeting of the Great Lakes Section in Midland, Mich., May 25 and 26. Left to right are Robert Lalk, head of the testing section at The Dow Chemical Company's coatings technical service; Donald L. Segur, development engineer in Dow's technical service and development; Dr. Norman Franz, associate professor of wood technology at the University of Michigan, the newly-elected section chairman; Henry A. Huber of Dow's technical service and development and a member of the program committee; L. I. Winebrenner, technical director for Protection Products Manufacturing Company, Kalamazoo, Mich.; Brooks Applegate of Travis Applegate Company, Grand Rapids, retiring chairman. and Dr. Turner Alfrey, Dow research scientist.

FPRS SPEAKERS AND COMMITTEE participating in the Maine District Meeting: front row, left to right, Winfred Hibbard, Passamaquoddy Lumber Co.; Frank Parrish, Heywood–Wakefield Co.; and Paul Graham, Clinic of Wood. Back row, left to right, Joseph Lupsha, Maine Forest Service, Chairman; Ronald Gale, Secretary–Treasurer, Northeast Section; Harold L. Moulton, National Lumber Manufacturers Assn.; Donald Saunders, President-elect, FPRS; and Fred Simmons, U. S. Forest Service.

## Great Lakes Section Holds Annual Meeting

About 50 members of the Great Lakes Section, Forest Products Research Society, attended their annual meeting at the home of The Dow Chemical Company in Midland, Michigan, May 25 and 26.

Brooks Applegate of Travis Applegate Company, Grand Rapids, retiring chairman, and Dr. Norman Franz, associate professor of wood technology, University of Michigan, the new chairman, presided.

The following papers were presented:

"Treatment of Utility Poles and Crossarms with a Water Repellent Preservative," by L. I. Winebrenner, technical director for Protection Products Manufacturing Company, Kalamazoo, Mich.

"Acrylic Coatings for Wood," by Robert Lalk, head of the testing section of Dow's coatings technical service.

"Theory of Adhesion," by Dr. Turner Alfrey, Dow research scientist.

"Flexible Urethane Foams," by Donald L. Segur, development engineer of Dow's technical service and development.

Dr. William C. Bauman, director of Dow's chemicals research, spoke at a dinner meeting Thursday, May 25. Henry A. Huber, Thomas E. Werkema and George E. Olson of Dow comprised the program committee.

Members of the Great Lakes Section are from northern Ohio, lower Michigan, Canada, Illinois and Wisconsin. This marked the first time they had ever met in Midland.

## Northeast Section Holds Joint Meeting With Maine Forest Products Council

Ninety-two sawmill operators and wood product manufacturers attended a joint meeting of the FPRS Northeast Section and the Maine Forest Products Council at the Worster House, Hallowell, Maine, April 28.

It was the first annual meeting of the 51-membered Maine Council, formed a few months ago to coordinate the efforts of Maine wood industry groups and promote the use of wood products. Officers and directors were elected at this meeting, and plans were made for the choosing of standing commitees.

The luncheon speaker was Harold L. Moulton of New York City, building code consultant for the National Lumber Manufacturers Association, Washington, D. C. Moulton outlined the activities of NLMA's Technical Services Division, which covers building codes, government specifications, engineering, education, publications, fire insurance, and technical promotion.

Fred C. Simmons of the Northeastern Forest Experiment Station, Upper Darby, Pa., discussed utilization problems of Maine softwoods. He reported that white pine lumber markets have shrunk to half the volume produced 10 years ago and the price received per 1,000 has declined about 30 percent, Simmons described research to develop replacement markets for these species, which includes end and edge gluing and paper overlays to upgrade pine lumber and make it more usable, and new high yield pulping processes.

Winfred Hibbard of Passamaquoddy Lumber Company, Bangor, Maine, discussed the need for sawmill modernization and quality control practices to simplify merchandising and provide more profit.

Paul Graham, Clinic of Wood, Newfane, Vermont, told the group that ". . . furniture and other major wood product manufacturers of the Northeast require a modern hardwood dimension operation that can serve both as their rough mill and finishing machine department. . . ."

Frank T. Parrish, Heywood–Wakefield Company, Gardner, Mass., emphasized the economic evolution of cut-to-size stock. "There is no reason," he said, "why milled-to-size stock can't be profitable and advantageous to both producer and consumer in the Northeast Market area."

Officers of the Maine Forest Products Council elected at the annual meeting are: Donald K. Saunders, Saunders Brothers, Westbrook, president; Joseph Sewall, J. W. Sewall Co., Old Town, vice president; Burton Wilner, Wilner Wood Products Co., Norway, treasurer; Austin Wilkins, Augusta, Maine Forest Commissioner, acting secretary.

**TWENTY-FIVE DRY KILN OPERATORS and others attending the 85th Kiln Drying Demonstration at the U. S. Forest Products Laboratory heard R. C. Rietz, staff engineer, lecture on the use of a recorder controller, a device used to regulate kiln temperatures.**

## USFPL Kiln-Drying Demonstration

The latest research findings on the practices and equipment used to season wood were explained to 25 men, mainly industry representatives, enrolled in the recent 85th Kiln Drying Demonstration at the U. S. Forest Products Laboratory, Madison, Wis. The 2-week demonstration stressed such subjects as kiln operation, drying schedules, air drying, moisture content of wood in use, and storage of wood.

"A movement stressing the importance of improved seasoning practices in the lumber producing regions of the United States, Mexico, and Canada is gaining more momentum," declared R. C. Rietz, in charge of wood seasoning research at the Forest Products Laboratory. He explained further that product quality is recognized as being associated directly with improved moisture content control during processing and fabrication.

Rietz visited seasoning experts in several foreign countries recently to review wood seasoning developments and to exchange technical information important to the wood seasoning research program under way at the Forest Products Laboratory.

"Our aim in offering these kiln drying demonstrations is to teach dry kiln operators and others the means whereby they can obtain increased efficiency in their own seasoning operations," Rietz added.

The analysis of problems common to the seasoning of wood is of basic importance. During the demonstration, the group studied actual wood products that developed defects in drying and were sent by industry representatives to the Laboratory for analysis. "The opportunity to evaluate the causes and remedies of defects in these pieces of wood offers the men practical experience that may have application in resolving problems associated with drying operations at their own plants," explained E. F. Rasmussen, Laboratory seasoning expert who directed the demonstration.

These training demonstrations have been held by Laboratory staff specialists since 1919. In addition to kiln operators, they annually attract such men as plant managers and other executives, engineers, lumber inspectors, yard and plant foremen, and wood technologists.

## State U. At Syracuse Plans Ninth Forestry Conference

The Ninth Northeastern Forest Tree Improvement Conference will be held Aug. 23 and 24 at the campus of the State University College of Forestry at Syracuse University, Syracuse, N. Y., it was announced. The Forest Tree Improvement Conference is another in a series of special events being held at the College of Forestry during 1961, the college's golden anniversary year.

The program for the two-day meeting will include a field trip through the college's Syracuse Forest Experiment Station to see a demonstration of work being conducted by the college in forest tree improvement and particularly the elm test area, and a tour of the Hugh P. Baker Memorial Wood Products Laboratory building on campus.

## Research News From Canada

**Log-Grading Techniques:** A demonstration of hardwood log-grading techniques—believed to be the first of its kind in Canada—was held in May at Duhamel, Quebec. It was designed to stress the importance of the use of log-grading techniques in the utilization of hardwood timber, and emphasized the need of implementing a quality appraisal system in the bucking of hardwood sawlogs. It was conducted by research officers of the Ottawa Laboratory, Forest Products Research Branch, Federal Department of Forestry and sponsored by the Singer Manufacturing Company, Duhamel, P. Q.

**Glulam:** Is it possible to make glued, laminated structural members from spruce? Defiinitely yes. It is technically feasible to manufacture glulam from any species which presents no particular gluing problem. Spruce, along with other commercial eastern species, such as hemlock, jack pine, red and white pine, have proved to be easy or moderately easy to glue, depending upon the adhesives used. This is why it is only natural to inquire why one seldom sees glulam structural members made from spruce or other eastern species. The strongest factor involved is an economic one.

These aspects and others are discussed in greater detail in "The Use of Eastern Canadian Wood in Glued Laminated Construction" by D. E. Kennedy. Copies of this article are available upon request.

**Scarf Joints:** The performance or effectiveness of end joints in individual laminations is an important factor in determining the strength of glued, laminated structural members, and end joints will occur in all but the shorter glulam members. The scarf joint which is used in end-jointing wood members, is a compromise between end- and side-grain gluing and the proportion of end grain decreases as the slope of the scarf decreases. Several tests, beginning in 1954, have been performed on the scarf joint to determine its efficiency. Information may be found in the Forest Products Research Branch Technical Note No. 9 "The Efficiency of Scarf Joints" by A. P. Jessome. Copies are available upon request.

**Ambrosia Beetles:** From a study made in 1957, it was estimated that lumber degrade to the value of about two and three-quarter million dollars was caused by ambrosia beetles on the coast of British Columbia during the year. The volume of logs infested was conservatively calculated at 25 percent and the average loss was $6 per M ft.b.m. The results of this study may be obtained by requesting "Lumber Degrade Caused by Ambrosia Beetles" by C. F. McBride and J. M. Kinghorn.

**Other Publications:** Other publications available from the Forest Products Research Branch of Canada include: Kiln-Drying of Lumber in Eastern Canada by R. S. Millet, T. N. No. 21; Design of Containers and Interior Packing by J. M. Rudnicki, T. N. No. 22; Tolerance of Some Fungi to a Water-Soluble Preservative and its Components by Madhosingh; Boiling and Impregnation in the Preservation of Round Western Hemlock by W. M. Conners and G. Bramhall; and Production, Manufacture and Transportation of Pulp Chips From Sawmill Residue in Eastern Canada by J. A. Doyle and I. B. Flann.

All of these publications are available upon request from the Forest Products Research Branch of Canada or by use of the Reader Service form.

## NEW PRODUCTS *and Literature*

### IBI Sets Insulating Rates for Fiberboard Sheathing

The Insulation Board Institute has established rated insulating values for the regular fiberboard sheathing produced by its 14 member companies.

Charles M. Gray, IBI manager, said surface-to-surface heat resistance values (R-values) have been set at R 2.06 for 25/32-inch insulation board sheathing and at R 1.32 for ½-inch fiberboard sheathing. He said the program marks the first time that a sheathing material has been rated for its insulating value by a trade group.

Starting this month, the 14 IBI member companies (which account for over 95% of all insulation board production) will begin stamping the "IBI Rated Seal" on their sheets of regular fiberboard sheathing. The seal itself will contain the IBI R-value rating for the two thicknesses. Eventually, the seal will appear on over 20 million sheets of insulation board sheathing in an average year.

**Circle Item 2**

### ASTM Publications List Now Available for 1961

The American Society for Testing Materials announces the availability of a 62-page list of publications. Published in April of this year, this list of publications describes the Symposiums, Manuals, Special Publications, Indexes, Compilation of Standards, Charts, Reference Photographs and Reports published by the Society through the years. More than 300 items are fully described, 40 of which are new and not previously listed.

The publications cover all phases of materials and their evaluations and are arranged conveniently by titles and subject. A convenient order blank is bound into the catalog. The list of publications may be obtained free for the asking from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

**Circle Item 3**

### Flat-Car Lumber Load

A new flat-car lumber load that allows loading and handling economies for both shippers and receivers has been authorized by the American Association of Railroads for unrestricted use by lumber shippers. The specifications for the new load for lumber 8 feet long or over were "published" as Fig. 6–B of Section 5, A.A.R. loading rules, on April 24, 1961, in a circular letter to A.A.R. member railroads. The 6–B load was developed by Signode Steel Strapping Co. in cooperation with interested shippers and the A.A.R.

It is the first A.A.A.-authorized flat car lumber load that does not limit the amount of vacant space across the car. This eliminates from Fig. 6–B the custom-fitted ladder braces and trusses that are required in other figures to fill out center gaps. Only four pairs of stub stakes are required.

To aid in realizing the economies of this new load, Signde has prepared a "6–B Package" which consists of a folder with cost comparisons and helpful information about the load, a materials list and loading diagram, the official specifications and drawing, and a 6–B loading and bracing checklist. The "6–B Package" may be obtained by writing.

**Circle Item 4**

### Hydraulic Cylinders

A new, high-quality line of 10,000 P.S.I. twin-cylinder, "center-hole" double-acting hydraulic cylinders with choice of stroke-length has been announced by the Precision Hydraulics Division of the Owatonna Tool Company, Owatonna, Minn., designers and manufacturers of hydraulic cylinders and power packages.

The new YDT series cylinders are available in bore sizes of two 1½-inch, two 2-inch, and two 2½-inch with "push" capacities of 17, 30, and 50 tons at 10,000 P.S.I. Cylinders are designed primarily as "push" cylinders but with sufficient "pull" (piston return) force to return the ram from such work as punching, forming, broaching, etc. where a spring-return would be inadequate. More information may be obtained.

**Circle Item 5**

### Dramatic Steel Building Relies on Treated Wood

When the revolutionary $20-million Pittsburgh Public Auditorium with its push-button, retractable dome is opened to the public late this summer, it justly will be hailed as one of the most imaginative applications for steel in the world.

However, few people realize that more than 90,000 lineal feet of specially treated Douglas-fir nailing strips stretch like open fingers from the rim to the top of the four-acre dome. The bottom of each of these pressure-treated strips is anchored to the steel roof deck with stainless steel screws. Extruded aluminum gutter bars are attached to the top of each wood strip. Wood strips at right angles are also used in a circumferential manner to form a firm basis for the horizontal seams in the stainless steel sheets. Above this network of wood nailers, the dome's stainless steel skin is spread over eight leaves, six of which are retractable.

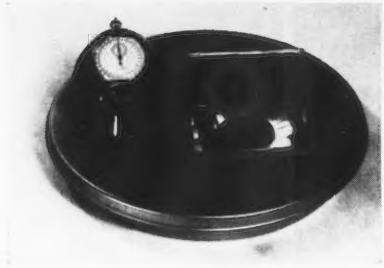
When the auditorium is dedicated and the dome is opened under Pittsburgh's summer skies, the pressure-treated nailing strips, supplied by West Elizabeth Lumber Company, West Elizabeth, Pennsylvania, under license of Koppers Company, Inc., will be starting a record of service that more expensive metal materials could not match.

**Circle Item 6**

### Stapling Tools

A completely revised and expanded catalog of industrial stapling tools has been published by the Paslode Co., a division of Signode Steel Strapping Co. The 20-page booklet includes detailed descriptions of the "Clipper," the first portable, air-powered, magazine-fed clip applicator for use in the assembly of spring units, Paslode's air power staplers and stapling pliers, stapling hammers, and tackers. The catalog may be obtained by request.

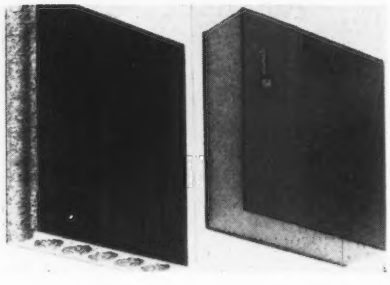
**Circle Item 7**



## Curl Sizing Tester For Paper

Thwing-Albert Instrument Company announces the new Carson Curl Sizing Tester for testing the degree of curl and sizing of papers up to ten thousandths of an inch in thickness. The new design features an improved timing system which permits the operator to make more precise measurements. It also features a totally enclosed liquid container that helps eliminate spills. Originally developed at the National Bureau of Standards, the Carson Curl Sizing Tester is built to conform to TAPPI Standard T–466 m–46. Write for more information.

**Circle Item 8**



## New Partition Panels

A new partition panel for office partitions, dividers in reception rooms and lobbies, washroom separators, and other institutional, commercial, and residential uses is announced by the Micarta Division of Westinghouse Electric Corporation. With surfacing of durable, maintenance-free decorative plastic laminate, the panels offer a choice of styrofoam or chipboard core. The sandwich is made by gluing 1/16-inch Micarta to both sides of the core. It is trimmed after gluing to remove the glue bead and square the edges. The partitions are simple to install and adjust, with custom cutting at the site of installation.

Introduction of the new partition panels marks the first time that a single manufacturer made a standard laminate-faced partition panel to fill the needs of most partitions joinery suppliers. Panels are available for about $1.50 per square foot. More information may be obtained.

**Circle Item 9**

## New Particleboard Standard

Architects, home builders, and furniture manufacturers can soon be assured of receiving quality particleboard by looking for the grade mark symbol of a newly established Commercial Standard, "CS236–61,"on each panel, according to the Commodity Standards Division, Office of Technical Services, U. S. Department of Commerce.

The new Standard, *CS236–61* for *Mat-Formed Wood Particleboard (Interior Use)*, was requested by the National Particleboard Association, for the purpose of providing quality criteria for this versatile wood product. It has just been endorsed by most manufacturers, and by a representative group of distributors and architects, as well as some furniture, plywood, and adhesive manufacturers. The standard became effective for new production from June 1, 1961.

Consideration is already being given by NPA to expanding this basic Standard to cover specific use standards for floor underlayment corestock for plywood, and for exterior sheathing.

**Circle Item 10**

## Vegetation Control

A comprehensive guide to effective and economical vegetation control in industrial areas has been produced by the Industrial and Biochemicals Department of the Du Pont Company. It can be useful in analyzing vegetation problems and selecting the right chemical or combination of chemicals to obtain the results desired. Selection of the proper chemical or chemicals for a specific control problem may depend upon differences in plant species, rainfall, soil types, and various economic factors. Proper use of this guide can provide the key to long-term, least-cost weed and brush control. Free copies may be obtained by writing.

**Circle Item 11**

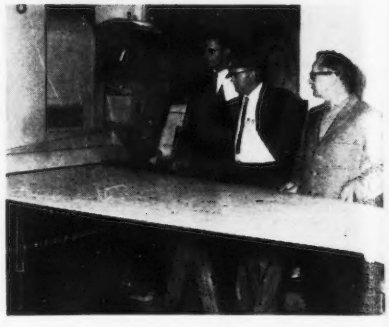
## Vacation Cabin and Fallout Shelter

In time for the annual summer exodus to the mountains and beaches, West Coast Lumbermen's Association has published complete do-it-yourself plans for a low-cost starter vacation cabin. Another new item in WCLA's spring promotion program is a do-it-yourself plan for an atomic fallout shelter.

Retailers can use the plans in three ways: 1) they can build the components in their yard and erect the cabin on site for their customers; 2) they can build and sell the panels only, letting the customer erect the cabin himself; or 3) they can sell the materials only, and let the customer do the building and erecting himself.

All three methods provide an excellent way for the retailer to use his short pieces of lumber and odd-sized doors and windows, and still make a profit on these hard-to-move items. These plans are available in quantity

**Circle Item 12**

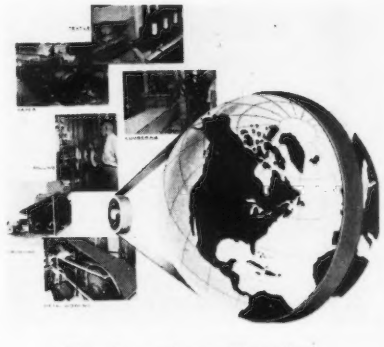


## Wide Belt Conversion Unit

A new Nylund wide belt conversion unit, designed to convert the Solem and other endless bed drum sanders to wide belt sanding, has been developed by Elford Plywood Machinery, Inc., Portland, Oregon. The Nylund conversion unit is easily adapted to the bed section of most models of endless bed sanders, and it can be installed with a minimum of downtime.

The first Nylund conversion unit is now in operation at the United States Plywood Corporation plant at Eureka, California, to be used for dimensioning and finish sanding. Further information on converting to wide belt sanding may be obtained.

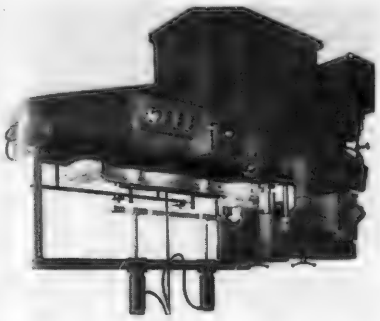
**Circle Item 13**



## Engineering Catalog

A new 12-page illustrated engineering catalog describes Extremultus flexible, oriented nylon-polymer core belting. The booklet features comprehensive engineering and application data, including graphs to determine the proper type belt, as well as charts for belt width and tension. The catalog may be requested.

**Circle Item 14**



## Profiling and Shaping Machine

The Ekstrom, Carlson and Co., Rockford, Illinois, has just announced the introduction of a new automatic profiling and shaping machine. Known as the PS–44 and PS–72, it is a two-side, two-spindle machine designed to shape straight or irregular edges on one side or opposite sides of wood parts.

Parts can be equally or unequally formed as they pass through the cutting cycle. Each head moves independently of the other, following the contour of its respective pattern. Parts that require shaping on one side only can be laid back-to-back or, parts can be stacked in multiples. Complete specifications, catalog bulletin, and prices may be written for.

**Circle Item 15**

## Moisture–Density Determinations

The TESTlab Corporation announces the availability of a 12-page technical brochure titled "Moisture-Density Determinations For Civil Engineering Works." The brochure describes in detail an improved nuclear system for taking rapid field measurements of soil, moisture content and soil density. The system consists briefly of a radioactive source, a detector for the source, and a scaler to indicate the amount of radiation detected. A relatively inexperienced operator can successfully use this completely portable system to obtain moisture or density determinations in a fraction of the time required by other methods.

The equipment has wide applications in highway, building and dam construction. It has been successfully used in determining density of asphaltic pavements and other material. Its uses in agricultural studies are tremendously varied, being used for controlled experiments on the relation of moisture to plant growth, studies of ground water movements and irrigation projects. Copies of the brochure will be submitted upon request.

**Circle Item 16**

## New Saw Blade

Deluxe Service Tool Corp. of 1108 Grand Ave., North Bergen, N.J., is adding a new style combination saw blade to their Luxite Line.

This carbide tipped circular saw blade, known as the Luxite 48 is designed specifically for greater ease of cutting solid woods, plywoods, laminates and composition materials. It can be used for both ripping and cross-cutting on hand feed operations, table variety or radial arm style machines.

The Luxite 48 has extra large carbide tips, (approximately 43 percent larger in total area than comparative blades). This increased tip size provides for many more resharpenings, thus longer blade life is realized. The blade is available in 8, 9, 10 and 12-inch diameters with standard bore sizes. Additional information and literature is available.

**Circle Item 17**

## Retirement Housing Market Potential Covered in Book

A concise, complete "Builder's Guide to the Retirement Home Market" that describes how any home builder or builder-dealer in any location can put together his own program is available from Douglas Fir Plywood Association, Tacoma 2, Wash. Charge for the book is 50 cents.

The tightly-written, well-illustrated volume is divided into seven sections. It was developed with data collected from research and from builder experience in all areas of the country and includes a set of study plans for House of Freedom, the successful retirement demonstration house developed by DFPA and the American Association of Retired Persons for the White House Conference on Aging.

The book provides up-to-date information on this big market and how to pinpoint it in any area of the country. Survey results provide detailed information on what buyers want in a house and in neighborhood and community facilities. Suggestions for locating land are specific and practical. Selling methods and financing opportunities are explained and lists of sources for additional information are included.

The House of Freedom project, which sprang from a conference of experts called by DFPA last November, is outlined, along with the results of questionnaires answered by White House Conference delegates.

The publication is topped off with a list of eight areas in which DFPA will offer specific promotional assistance to builders interested in tying in with the association's retirement housing campaign.

**Circle Item 18**

## Protective Mesh For Poles

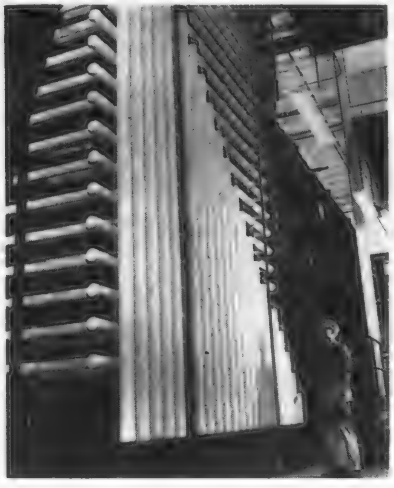
A woven steel wire mesh, produced by U. S. Steel's American Steel and Wire division, today is helping to solve a knotty problem for some of the nation's electric power companies and gives promise of saving the industry sizeable sums in the cost of replacement of utility poles.

Known in the trade as industrial wire cloth, the mesh has been used in wooded areas in the South and other sections to combat forays by woodpeckers, which for years have played havoc with utility poles. Often, the razor-billed birds begin their assault on the poles even before construction crews leave the job. (In heavily-forested regions, poles with a normal life expectancy of 30 to 35 years have required replacing after only a few years of service).

Various other methods have been employed in an effort to check the problem. The old poles have been left standing, but the woodpeckers, apparently drawn by some as yet undiscovered attraction, quickly move to the new ones. Even the placement of metal snakes on the poles have failed to deter them. With installation of the ½-inch, 19 gage wire mesh, heavily galvanized for long life, the onslaught is ended.

In applying the wire cloth, poles are completely covered from the top to a point 12 feet above the ground. The wire is overlapped 2 inches horizontally and vertically. Installation is horizontal, since pole taper and wire stiffness make vertical installation more difficult. Pole tops are capped, and wire is notched around the arms. Initially, the wire was terminated 20 feet above the ground, but it was found necessary in certain areas to modify this to the 12-foot height.

**Circle Item 19**



## U.S. Plywood Opens New $3½ Million Novoply Operation

United States Plywood Corporation opened a $3½ million plant last month in South Boston, Va., and became the world's leading particle board producer.

The new highly-automated facility is designed to produce initially the equivalent of 30 million square feet of ¾" board a year. When added to production capacity at the firm's Anderson, California, plant, U. S. Plywood will be able to turn out 80 million square feet of its patented, 3-ply Novoply board annually.

S. W. Antoville, U. S. Plywood chairman and chief executive officer, told guests and members of the press assembled at the 40-acre plant site, that the firm's investment will have a "two-way" return.

"With our new plant in full production at present capacity, we expect to increase annual sales volume at the distribution level by about $7 million," Mr. Antoville declared, "and at the same time, our plant will bring millions of dollars a year in new income into this area in purchase of our raw materials from tree farmers, in additional payrolls, increased freight and supplies."

Congressman William M. Tuck, former governor of the Commonwealth of Virginia, in his introduction heralded the new U.S. Plywood operation as a "boon to Halifax County's tobacco-tired economy."

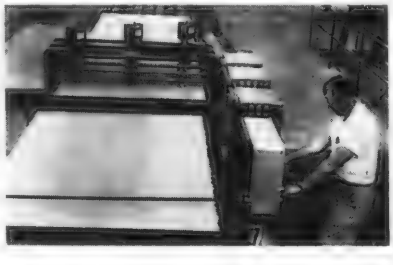
About 50,000 cords of southern pine a year will be purchased locally to operate the plant at the outset, according to Gene C. Brewer, the firm's president, and buying from farmers will be on a "year round basis, rather than seasonal as are traditional farm crops."

But the company will not depend entirely upon outside purchases for basic raw material, Mr. Brewer said. U. S. Plywood has already acquired several thousand acres of timber land in Halifax county and in nearby North Carolina. This land, he said, will be managed on a "tree farm" basis to provide a source of supply that in the future will meet half the plant's yearly needs.

"With anticipated increased demand for Novoply, however, I expect that our purchases from tree farmers in the area will rise above our present $¾ million annual requirements," he said.

### Fastest Growing Forest Product

Mr. Brewer told his audience at a Halifax County Chamber of Commerce luncheon, held under canvas adjacent to the plant, that when the company began production of Novoply ten years ago in Anderson, California, particle board was virtually unknown in the United States. "Today, it is the fastest growing forest product on the market," he said. "Its growth rate of about 38 per cent a year for the past five years has brought production in the industry to more than 300 million square feet annually and we have seen it replace many conventional materials."



The building materials executive added that "in many instances, Novoply has proved better suited to our customer's requirements than plywood and lumber because of the technological improvements engineered into the raw material." He referred especially to variable thicknesses possible in large size panels, extremely flat, hard and smooth surfaces and virtually warp-free characteristics that are not found in wood as it comes from the forest.

"Novoply," he said, "is the wood nature should have made."

## Wood Promotion Program Stepped Up by NLMA

"The lumber industry is no longer taken for granted," A. B. Hood, President of the National Lumber Manufacturers Association declared before the group's Spring meeting at New Orleans in May.

Forthright action by the Board of NLMA and by the National Wood Promotion Committee during the sessions at the Royal Orleans Hotel reflected Hood's assertion that the lumber industry is "rapidly earning a label that connotes progress and vitality."

Eliot Jenkins, Chairman of the National Wood Promotion Committee, announced that actions by federated member associations of NLMA has assured that the 2-year old wood promotion program would be stepped up beginning in June from a 10-cent per thousand board feet of production rate to a 16-cent rate. The new program calls for a projected annual budget of $2,053,000 in 1962.

The NWPC also recommended to the regionals that: when consideration is given to consolidation of the NLMA and NWPP into a combined Board and Committee structure, it is recommended that consideration be given also to making support for the National Wood Promotion Program a part of the NLMA dues structure.

## New FPRB Publication "Span Tables"

An important development, which will affect many Canadian builders, was described in the March 15 issue of the Forest Products Research Branch RESEARCH NEWS under the title of "New Span Tables and Grade-Marked Lumber." The announcement of February 8, 1961, by the Central Mortgage and Housing Corporation forecast that grade-marked lumber will be required for NHA houses built under the new Canadian housing code. When the new Housing Standards, now being prepared, become effective on January 1, 1962, a set of tables will be included, showing the maximum spans permitted for joists and rafters in the various species and grades of Canadian lumber.

These Tables have now been printed as Forest Products Research Branch Technical Note No. 30 for the advance information of lumbermen and builders. This 48-page publication contains a preamble covering lumber grades, grade strengths, species strengths, allowable unit strengths, design assumptions, grade and span relationship, as well as 36 pages of Span Tables for the various eastern and western species.

Copies of FPRB Technical Note No. 30 entitled "Span Tables For Wood Joists And Rafters For Housing" are available on request from: Forest Products Research Branch, Department of Forestry, Ottawa, Ontario; or the Vancouver Laboratory, Forest Products Research Branch, Department of Forestry, 6620 N. W. Marine Drive, Vancouver 8, B. C.

## International Conference on Timber Engineering

The first International Conference on Timber Engineering is to be held at the University of Southampton, from Sept. 18 to 23, 1961. It is being organized jointly by the University of Southampton and the Timber Development Association. Papers will be presented to the Conference under four main headings: description, construction, design, and research, as well as papers on the economics of timber roofing, international developments in the design and consrtuction of timber shells and folded plates, methods of jointing and testing of timber roof structures. Part of the Conference will be devoted to site visits also.

Australia, Austria, Czechoslovakia, France, Holland, India, Norway, Poland, Russia, and the U.S.A. will be among the countries represented at the Conference. The conference secretary is Dr. H. G. Allen and requests for further information should be addressed to him at the Department of Civil Engineering, University of Southampton, Southampton, England.

## Scientific Research

Almost 70,000 of the scientists and engineers at U. S. colleges and universities during 1958—44 percent of the total—were engaged in research and development, the National Science Foundation reported. By field of science, the scientists and engineers were employed as follows: in the life sciences, 47 percent; physical sciences, 26 percent; engineering sciences, 17 percent; and social sciences, 10 percent.

These findings of a survey on the expenditures and manpower resources in research and development in colleges and universities for the year 1958 are announced in *Reviews of Data on Research & Development,* No. 27, "Scientists and Engineers Engaged in Research and Development in Colleges and Universities, 1958," just released.

Conducted for the National Science Foundation by the Department of Health, Education, and Welfare, Office of Education, the survey obtained data by means of questionnaires mailed to 1,916 independent and autonomous institutions of higher education in the United States.

Copies of the publication may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. for 10 cents.

## Schools on Veneer Splicing

The G. M. Diehl Machine Works inaugurated a continuing series of full-day schools for woodworking machine operators and maintenance men on June 19, in Statesville, North Carolina, at the plant and showrooms of the Garrison Machinery Company. The first of these one-day Diehl "clinics" concerned itself exclusively with tapeless veneer splicing. It will be repeated daily for classes of 25 to 30 men and women at a time until all interested plants in the area have been serviced. Over 125 reservations have already been made by "students" from some 35 plants in the Carolinas–Georgia–Tennessee–Virginia district.

Following the veneer-splicer schools (at intervals of perhaps a month) will be others devoted to different classes of woodworking machinery: ripsaws, molders, lathes. Possible future locations for repeating the entire educational program in other furniture production areas include Boston, Dallas, and the Diehl home plant in Wabash, Indiana.

## Western Forest Industry

*Western Forest Industry: An Economic Outlook,* a study of the forest products industries of the Pacific Slope, with projections to 1975, has just been published for Resources for the Future by the Johns Hopkins Press. John A. Guthrie and George R. Armstrong are the authors.

The area covered consists of the "eleven western states" (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming), the new state of Alaska, and the Canadian province of British Columbia. Principal industries dealt with are lumber, pulp and paper, and plywood and veneer. These three industries, the authors point out, are growing rapidly on the Pacific Slope.

The authors trace the economic possibilities for western forest industries in the light of expected changes in population, technology, raw material supplies, location of markets, and competitive relations with other major producing regions, particularly the southern states. They also consider the implications of forest policy alternatives, of the concept of sustained yield, and of possible changes in management practices to meet further situations.

The 350-page book includes charts and tables, and a 20- by 28-inch map in color of major forest types of the Pacific Slope. Priced at $6.50, it is available through booksellers or from The Johns Hopkins Press, Baltimore 18, Maryland.

## Lumber Drying and Kiln Operation

Solutions to many problems of lumber drying and dry kiln operation and maintenance can be found in the Dry Kiln Operator's Manual, Agriculture Handbook No. 188, a new publication just issued by the U. S. Department of Agriculture.

The 197-page illustrated manual was authored by E. F. Rasmussen, dry kiln specialist at the U. S. Forest Products Laboratory, Madison, Wis., with contributions from wood seasoning experts at the Laboratory and other units of the Forest Service.

Directed primarily to owners and operators of dry kilns, the manual also contains information on the theory and practice of kiln drying, making it especially valuable as a text to students of wood technology, dry kiln manufacturers, and producers of wood products in general.

The Forest Products Laboratory pioneered research on modern forced-air-circulation dry kilns in the twenties and holds basic public patents on them. The Dry Kiln Operator's Manual summarizes much research and development done since that time, both at the federal laboratory and elsewhere. Copies may be obtained.

## Fire Protection

Protection of the nation's forests from fire cost taxpayers more than $104 million during fiscal 1960, or 57 cents per citizen, according to *American Tree Farmer* and the *Forestry Digest.* Meanwhile, pointing to weaknesses in state and Federal fire protection systems, the Western Pine Association recently adopted a seven-point program aimed at strengthening forest protection in California and throughout the West.

The program: 1) more aggressive initial attack on all fires; 2) better use of local, experienced men in planning control work, and in control work; 3) a single general headquarters on cooperatively fought fires, fully organized for adequate liaison between agencies; 4) adequate, cooperative preplanning for emergencies; 5) no debris burning during periods of hazardous weather; 6) boards of review to sit in judgment after each major fire, and these boards should include industry representatives; 7) a state, Federal and industry conference to evaluate fire protection needs and to realign the programs for greater effectiveness.—*The Lumber Letter, NLMA.*

# CROSS SECTION

## . . . Voice of Membership

### Letter From The Editor

John P. Howe, Secretary Treasurer
Northwest Wood Products Clinic
College of Forestry, University of Idaho
Moscow, Idaho.

*Dear John:* Thanks for calling our attention to the fact that we neglected to mention that Bob Hoyle's excellent article, "A Nondestructive Test for Stiffness of Structural Lumber," which we published in June, had been presented at the joint meeting of the Northwest Wood Products Clinic and the Inland Empire Section of FPRS last April.

This was purely unintentional. We are always pleased to give credit where credit is due, and the Clinic is a most deserving organization. We are also proud of the arrangement between NWPC and the Inland Empire Section and appreciative of the cooperation you have extended in the past.

Very truly yours,
JOHN K. MCDONALD, Editor
Forest Products Journal

### Continuing Membership

*Gentlemen:* The March issue of *Cross Section* requested comments from FPRS members regarding the possibilities of special membership fees for both retired and military personnel.

To draw from the writer's own experience, as a member of The Photography Society of America, please note that while on active duty with the U. S. Navy for over three years, annual dues were cancelled, while still retaining all privileges of regular membership. Whether or not, this is still in effect at this time is unknown. However, this cancellation of dues was not applicable to those individuals who chose to remain in the service as a career. If cancellation of dues is not feasible, it would seem logical to treat service personnel similar to those in a student capacity because they cannot participate actively in FPRS.

The writer agrees with Mr. Ira Hatfield that retired people should receive consideration in regards to reduced dues.

Very truly yours,
L. EISEN
Noblesville, Ind.

### Plenum Floors

*Gentlemen:* You will be interested in an article which is due to appear in the *NAHB Journal of Homebuilding* sometime within the next couple of months. This concerns the operations of a builder near Newark, Ohio, who used my bulletin on "Plenum Floor Construction for Homes" and thus far has built eight houses. Since, as you know, the lumber industries have been losing about a billion board feet of business to slab floors in recent years, I think this quote from the man's letter will interest you. (note: he used treated wood blocks instead of my metal W's).

"We now have eight residential units in operation with the "plenum-on-grade" system and to date everything has proven highly satisfactory. We currently have thirteen additional units under construction to be completed by late summer, for a total of twenty-one individual residential units utilizing the 'plenum-on-grade' system.

"The eight units now in operation utilize the treated wood block supporting systems with the 2x4 floor joists being spaced 16" o. c. and supported by wood blocks 24" o. c. Carrier gas heating units were used with the bonnet temperatures being lowered to approximately 110 degrees discharge. We chose the technique of framing the entire sub-floor before placement of the non-load bearing interior partitions with the exception of the plumbing wall. The plenum space under the floor was utilized for the entire plumbing system and special permission was obtained from the City electrical code people to utilize this space for the running of electrical distribution cables. With this new technique, we are now able to give resilient hardwood flooring for the same price as we formerly were able to furnish asphalt tile on concrete slab."

Maybe all my struggle to get this construction system across will pay off some day!

Sincerely,
G. J. STOUT
State College, Pa.

## COMING EVENTS

**July 17–19:** Annual Meeting, Philippine Mahogany Association, Inc., Harvest House, Boulder, Colo.

★

**July 30–Aug. 2:** Sixteenth Annual Meeting, Soil Conservation Society of America, Purdue University campus, West Lafayette, Ind.

★

**Aug. 1:** Summer Meeting, Ponderosa Pine Woodwork, Fairmont Hotel, San Francisco, Calif.

★

**Aug. 2:** Summer Meeting, National Woodwork Manufacturers Association, Fairmont Hotel, San Francisco, Calif.

★

**Sept. 13–14:** Northern Hardwood and Pine Manufacturers Assn., Northland Hotel, Green Bay, Wis.

★

**Sept. 13–15:** Semi-annual Meetings, Western Pine Association, Multnomah Hotel, Portland, Ore.

★

**Sept. 14–16:** Annual Meeting, 16th Annual Lake States Logging Congress, Timber Producers Assn., Green Bay, Wis.

★

**Sept. 16–19:** Annual Convention, National Assn. Furniture Mfrs., Hilton Hotel, Chicago, Ill.

★

**Sept. 17–20:** Annual Convention, International Concatenated Order of Hoo-Hoo, Hotel Americana, Miami Beach, Fla.

★

**Sept. 22:** FPRS Upper Mississippi Valley Fall Meeting, Research Center, Minnesota Mining & Manufacturing Co., St. Paul Minn.

★

**Oct. 11–13:** FPRS Mid-South Section Meeting, King Edward Hotel, Jackson, Miss.

★

**Oct. 19–20:** Annual Fall Meeting, FPRS Midwest Section. Theme: Wood Composition Board, McCormick Place, Chicago, Ill.

★

**Oct. 27–28:** FPRS Inland Empire Fall Meeting, Washington State University, Pullman, Wash.

★

**Nov. 2–3:** FPRS Northeast Section Fall Meeting, Hotel Prince George, New York City.

★

**Nov. 4–7:** National Retail Lumber Dealers Association, Exposition, McCormick Place, Chicago, Ill.

★

**Nov. 6–8:** 1961 Pacific Logging Congress, St. Francis Hotel, San Francisco, Calif

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POLYESTER FINISHES enhance the beauty, warmth, and character of the wood. The problem of color matching, which is often a plant headache with pressure laminated plastics, is greatly eliminated. Extreme clarity results with a 6 to 10 mil cost.

# Production with Polyester Finishes[1]

JOHN W. PICTON
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**Many production men feel that polyester coatings are unique but impractical. For a time, the author was inclined to agree. His first week with a polyester system brought "trouble on trouble." Since then, however, the system has been used to finish thousands of cherry and walnut bedroom suites with few problems.**

THE TURNING POINT in the history of furniture finishes came with the advent of lacquers in the 1920's. Prior to this, varnishes and shellac were mainly used. The varnishes were slow drying, became brittle with age, and were poor for color and color retention. Lacquers gave the furniture people the opportunity to utilize conveyors. Since they dry fast and are easy to apply and polish, they are used today in larger volume than any other finish.

Lacquers are materials that dry by solvent evaporation. The most common lacquer is the nitrocellulose-type. Since the nitrocellulose molecules are large and polar, expensive solvents are required to dissolve them. Even then, cold spray lacquers contain only 24 to 27 percent solids. The lacquer film on a piece of furniture is primarily the same as the solid portion of the lacquer in a gallon of paint. The same solvents that carried the lacquer initially will likewise dissolve it off the furniture. Nail polish remover will remove a lacquer coating. Alcohol will not dissolve a lacquer film, but could swell or blister it and leave an ugly spot. Nitrocellulose molecules are linear and, therefore, lacquers give poor resistance to scratching, marring, and staining. Mustard, lipstick, and nail polish will readily stain a nitrocellulose lacquer film. The color stability of lacquers is only fair. They have good resistance to humidity and have good clarity. They resist chemicals and such weak acids as vinegar and diluted sulphuric. However, concentrated acetic and sulphuric attack the film almost immediately. The average lacquer film softens under a vinyl plastic, such as plastic cushions and will even burn with an aluminum foil glued beneath the top veneer. One coat of a cold spray lacquer will produce a film of about a mil and one-half at the cost of approximately 4 cents per square foot, assuming a 30 percent loss by spray.

Urea synthetic molecules are small in comparison to lacquer molecules and therefore lower cost solvents are used. Solids from 37 to 45 percent at cold spray viscosity are obtained. When the solvent leaves the film, the molecules with an acid catalyst tie together and form large three-dimensional insoluble structures. Urea synthetics have good resistance to solvents and to marring and scratching. They have fairly good stain resistance and are not affected by nail polish and coffee. Mustard, however, will leave a spot. Water white urea synthetics are color stable today, although many regular lower cost types are marketed for dark walnuts and where color stability is not required. Today urea synthetics have fairly good humidity resistance. However, we still hear that in some areas in Georgia and Florida the furniture turns sticky during the hot humid summer months. The clarity of ureas is fairly good and comparable to lacquer on all woods except the red mahogany and black finishes. Ureas return good chemical and heat resistance. The film is not softened by vinyl plastics. Used in the beautyguard system, good burn resistance is obtained. One coat of a cold spray urea will produce a dry film of approximately 2½ mils at the cost of 4½ cents per square foot.

Polyester coatings are unique in that the solvent portion used to carry the resin becomes part of the resin during the catalyzed cure. Hence, they are referred to as 100 percent solid materials. Often the paint formulator finds it necessary to add solvent that does not become part of the film, and polyesters are formulated at from 85 to 100 percent.

A cured polyester film is an insoluble three-dimensional structure. It resists solvents well. It surpasses urea synthetics in resisting trapped nail polish remover. It also has exceptionally good resistance to marring, scratching, staining, humidity, and chemicals. The clarity is at least equal to that of lacquer and many claim that it is superior. It has good burn resistance when used in the "Finishield" system.

The Author: J. W. Picton was graduated from the University of Manitoba, Winnipeg, 1954, with a B. S. Honors Degree. He worked in the Paint Research Laboratory, Canadian Industries Ltd., Toronto, Ontario, previous to joining Lenoir Wood Finishing Company where he is continuing development work in sythetics.

[1] Presented at the annual fall meeting of the Carolinas–Chesapeake Section, Nov. 11, in Raleigh, N. C. Approved for publication March 1961.

TO PREVENT FISH EYES the air was "cleaned" before it entered the spray gun by bubbling it through a 25-gallon pressure pot filled about one-third full with alcohol.

POLYESTERS PRODUCE tougher, harder films than common finishes. Where three machines were used in the rub room on urea synthetics, five were needed on the crystal plastic polyesters.

The color stability is fairly good, and it is somewhat superior to most lacquers in this respect, but not as good as a water white urea or an acrylic butyrate lacquer. The promoter used to cure polyesters is purple in color which prevents polyesters from being used on completely white suites of furniture. On eggshell-white, it is satisfactory. One coat will produce from 6 to 10 mils dry film at the cost of approximate 10 cents. (A comparison of lacquers, urea synthetics, and polyesters may be seen in the table.)

### Polyester System

The polyester system will probably vary with the supplier. Differences will probably be found in the washcoats, fillers, and topcoats, particularly in the topcoat. Some topcoats will be wax-free, others not. Some topcoats will require special equipment such as catalyst guns; others will be a two-coat system.

Our particular system is designed to approximate conventional lacquer and urea systems; no special equipment is necessary. Unless radically different, the general class of non-grain-raising (NGR) or water stains may be used. Our washcoats and toner are of the lacquer nature (drying by solvent evaporation) and are similar to conventional materials. They require a normal drying time of about 20 to 30 minutes. Our wiping stains, fillers, and glazes are the easy-wiping synthetic type and are reduced, applied, and dried in the conventional manner. The edging enamels and tracing stains are compatible with the system and have working and drying properties equal to conventional materials. The crystal plastic buildcoat is specially formulated and requires a catalyst. It requires 45 minutes to dry and then in topcoated with our crystal plastic polyester topcoat. The buildcoat is so designed that it easily releases the catalyst to the topcoat and promotes cure. The pot life of the catalyzed buildcoat is within the practical limits of one week. The polyester topcoat comes ready to spray and has a normal life of from 3 to 4 months. Where desired, the topcoat could be supplied in two packages and the life could be extended to about one year. Where the sealer/buildcoat system cannot be used, we have a specially formulated sealer to which catalyst can be added and then polyester topcoat applied. This process works on closed and semi-closed grain woods such as maple, cherry, and walnut. The sealer-buildcoat is preferred, however, on mahogany and oak. On woods such as maple, a finish may be obtained by using three coats, namely NGR stain, buildcoat and topcoat.

### Plant Production

Modifications in formulation and plant conditions may be necessary to overcome the difficulties in production. Some of the problems we encountered were:

**Cratering:** Since oil and polyester are incompatible, cratering (or fish eyes) results. The oil was removed from the air line by bubbling it through alcohol in a 25-gallon pressure pot. An adjacent problem was rub-room dust. The plant where we encountered difficulty had the rub-room one story above the finishing room.

**A COMPARISON OF LACQUER, UREA SYNTHETIC, AND POLYESTER FINISHES**

| | Lacquers | Urea Synthetics | Polyester |
|---|---|---|---|
| Solids—cold spray viscosity | 24 to 27% | 37 to 45% | 85 to 100% |
| Solvent resistance | Poor | Good | Very good |
| Mar and scratch resistance | Poor | Good | Fairly good |
| Stain resistance | Fair | Fairly good | Very good |
| Color stability | Fair to good | Very good | Very good |
| Humidity resistance | Very good | Poor–fairly good | Very good |
| Clarity | Very good | Fairly good | Very good |
| Chemical resistance | Fair | Good | Very good |
| Burn and heat resistance | Poor | Good | Very good |
| Build one coat | 1½ mils | 2½ mils | 6 to 10 mils |
| Cost—square foot one coat | 4¢ | 4½¢ | 10¢ |

The rub-room air was exhausted over the roof which contained an air vent leading to the sealer dry area. It was necessary to seal the air vent. Rubbing and polishing compounds contain oil and silicone materials, or both, and cause polyester topcoats to crater.

Draft was also a problem. Polyester topcoats are sensitive to air currents for approximately 5 minutes after spraying. In the plant, the topcoat spray booths were contained in a tunnel-like structure. The spray booth exhaust fans caused excessive air movement alone the conveyor line. It was necessary to cut a hole along the bottom of the wall opposite to spray booths to minimize air movement. When modification was made on these three conditions (oil, rubroom, and draft), the plant ran smoothly.

**Poor Drying:** It was found that temperature and humidity interfere with the cure of polyester topcoats. The temperature should not be more than from 100° to 110°F. for 45 minutes after spraying (or until the wax flows to the surface) and should be above 65°F. for good cure. In one instance, coated cases placed near an open window on a rainy day showed poor cure.

**Poor Flow:** It is necessary to find by trial and error the optimum air pressure and fluid delivery rate. With regular pumping equipment and a spray gun equipped with an FX needle and tip and a No. 705 cap, we found the best air pressure to be from 45 to 48 pounds per square inch with fluid pressure of 12 pounds per square inch. The pressures, of course, depend on the length of the hose.

Polyesters are considerably tougher and harder than other common finishes and more work is necessitated to cut the film. In a rub-room where three machines were used on a urea synthetic, it was necessary to go to five machines with our crystal plastic polyester to meet production.

### Advantages of Polyester Plastic

Polyester plastic has several advantages over laminated plastic. Since polyesters are sprayed on wood, the warmth and character of wood can be retained. With the coating 6 to 10 mils thick, extreme clarity and depth results.

Color matching wood to a pressure laminated plastic top is often a plant problem. The color difference between the tops, fronts, and sides is greatly eliminated by the use of polyester plastic all over the case. In case of damage, polyester finishes are easily repaired, whereas pressure laminated tops are difficult to repair.

Polyester sheens can be rubbed to a sheen variation from a dull satin to a full gloss. The face of a laminated plastic costs approximately 42 cents a square foot; polyesters cost approximately 10 cents per square foot.

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***A COMPARISON OF:***

# Hot Press Interior Plywood Adhesives[1]

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**Competition from other building materials and a need for better quality plywood may force the manufacturer into using adhesives that are more tolerant of moisture. From this aspect, one might find that phenolic adhesives will be used more prominently, despite the lower-cost advantage of blood/soya adhesives.**

FOR THOUSANDS OF YEARS, woodworkers have used various adhesives in the manufacture of their products. This use of these adhesives appears to have been an art rather than a science. The little known about them was a guarded secret. It was not until the early part of this century that much consideration was given to the theory of adhesion, or to the use of different compounds to produce adhesives for various uses. Since the gluing of the first Douglas-fir plywood panel in 1905, the formulation and use of adhesives has grown tremendously on the West Coast.

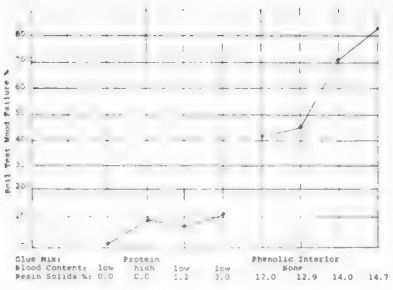
### West Coast History of Interior Gluing

The first interior Douglas-fir plywood panel produced on the West Coast was in Portland, Oregon, in 1905. The adhesive employed was hot animal glue applied to the veneers with paint brushes. The operation was slow as the panels necessarily were clamped overnight. The use of hot animal glue disappeared quickly as the process was slow, "messy," and produced inferior quality glue bonds.

Later, starch, vegetable, and casein adhesives were used in interior Douglas-fir plywood. These adhesives were better than the animal types but still failed to provide the glue-line quality desired by the "using public." These glues were hardly water resistant, much less waterproof.

In 1922, the industry still used casein adhesives. The inferior and expensive casein glues of this era led to the development of more water-resistant and less-expensive types. Cold-press soybean glues became available about 1926. The advent of soybean adhesives marked the first advance in glue-line quality for producing interior Douglas-fir plywood. (Later soya and blood/soya glues were used in making hot-press interior plywood.) Soybean glues in a modified form are still used in the softwood plywood industry. Superior quality casein type glues have been developed and are still used today; however, glue-line costs

[1] Presented at the Forest Products Research Society Meeting, Tacoma, Wash., Oct. 18, 1960. Approved for publication April, 1960.




A COMPARISON of adhesive type to bond quality

Table 1.—COMPARISON OF ADHESIVE TYPE TO GLUE-LINE COST

| Adhesive | Blood Content in Dry Glue | Resin Solids in Mixed Glue, Percent | Glue Line Cost Per M (⅜-inch Basis)* |
|---|---|---|---|
| Unfortified | | | |
| Blood/soya | low | 0.0 | $2.08 |
| Blood/soya toxic | low | .0 | 2.18 |
| Blood/soya | high | .0 | 2.11 |
| Blood/soya toxic | high | .0 | 2.20 |
| Fortified with phenolic resin | | | |
| Blood/soya toxic | low | 1.2 | 2.38 |
| Blood/soya toxic | low | 3.0 | 2.77 |
| Blood/soya toxic | high | 1.1 | 2.39 |
| Blood/soya toxic | high | 1.9 | 2.57 |
| Blood/soya toxic | high | 2.9 | 2.82 |
| Phenolic toxic | none | 14.8 | 3.08 |
| Phenolic toxic | none | 16.4 | 3.25 |
| Phenolic toxic | none | 17.8 | 3.53 |
| Phenolic toxic | none | 20.3 | 3.70 |

* Based on current prices as of September 15, 1960.

are much higher than for straight soybean glues.

The first soya adhesives were an improvement over prior adhesives, but the industry was still plagued by low glue-line quality. Until 1934, all Douglas-fir plywood produced was interior cold pressed. In 1934, the first hot press on the West Coast was used in making exterior plywood, with a phenolic type resin. These two events were the most outstanding achievements in the history of the softwood plywood industry. Hot pressing made it possible for today's use of a myriad of adhesives. The production of exterior plywood marked the first use of a synthetic product (resin) in gluing. Resins today are versatile and allow much flexibility in the variety of plywood products produced.

The advancement of adhesives and technology of gluing grew rapidly from the 1930's to the present. In 1939, blood/soya interior hot-press adhesives found their way into the softwood plywood industry. Blood/soya adhesives are considered an improvement over the cold-pressed soybean glues common to the industry. Later, modifications of the exterior phenolics were made to produce interior phenolic adhesives. Interior phenolic glues possess even higher quality glue bonds than are obtainable with blood/soya types.

## Interior Hot-Press Gluing Process

The various types of interior hot-press adhesives for gluing softwood plywood may be classified as 1) protein adhesives, and 2) phenol-formaldehyde adhesives. Protein adhesives include blood glues, blood/soya glues, and fortified blood or blood/soya glues (phenol resins). Phenol-formaldehyde adhesives include bark flour extended glues, Furafil*-extended glues, and walnut-shell flour extended glues.

* Furafil is a Quaker Oats Co. by-product of the furfural alcohol process.

Of these categories, the blood/soya and furafil-extended phenolics are probably the commonest interior glues used in the softwood plywood industry today. Characteristically, the extended phenolics produce the best quality glue bonds as opposed to blood/soya types.

**Phenol-formaldehyde Adhesives:** Phenol-formaldehyde resins are manufactured in large reactors of 2,000 to 10,000 gallons capacity. Specified quantities of phenol, formaldehyde, water, caustic soda, and other ingredients are added to the reactor and "cooked" under vacuum and atmospheric pressure for a certain length of time. After the cooking period, the phenolic resins appear as a dark-red viscous syrup of from 41 to 50 percent solids content, depending upon its end-use formulation. The resin is then cooled to room temperature and either "drummed out" or pumped into storage tanks ready for shipment. A typical interior phenolic adhesive is prepared in the mill by mixing water, furafil extender (or other extender), caustic soda, and soda ash together, forming a viscous mass. These ingredients are mixed for about 20 minutes, cooled, and the phenolic resin added. The mixed adhesives is rather low in viscosity and is almost black in color. After the mixing procedure, the adhesive is pumped to a holding tank. From the holding tank the glue is again pumped, this time to the glue spreaders. At the glue spreaders. the plywood panels are assembled in a conventional manner, followed by pressing in a multi-opening hot press.

Table 2.—TYPICAL GLUE MIXING PROCEDURES AND COST CALCULATIONS

A. Interior Phenolic Adhesive

| | Weight | Unit Price | Cost |
|---|---|---|---|
| Water @ 70°F. | 300 lbs. | | |
| Furafil 100-S Extender | 125 lbs. | $0.0385 | $ 4.81 |
| Mix 2 minutes | | | |
| 50% Caustic Solution | 50 lbs. | 0.0150 | 0.75 |
| Mix 2 minutes | | | |
| Soda Ash | 30 lbs. | 0.0350 | 1.05 |
| Mix 15 minutes | | | |
| Cool Mix | | | |
| 41% Phenolic Resin | 500 lbs. | | 48.75 |
| Stove Oil | 2½ lbs. | 0.0300 | 0.08 |
| Mix 5 min. | | | |
| Total | 1007½ lbs. | | $55.44 |
| Cost/lb. | | | $ 0.0551 |
| Average Spread | | | 56 lb/MDGL |
| Cost/MDGL | | | $ 3.08 |
| Cost+20% waste | | | $ 3.70 |

B. Interior Protein Adhesive

| | Weight | Unit Price | Cost |
|---|---|---|---|
| Water @ 70° F. | 150 lbs. | | |
| Dry Glue Powder | 85 lbs. | $0.1130 | $ 9.60 |
| Mix 5 minutes | | | |
| Water @ 70°F. | 215 lbs. | | |
| Mix 2 minutes | | | |
| 33⅓% Lime Solution | 28 lbs. | 0.0058 | 0.16 |
| Mix 1 minute | | | |
| 50% Caustic Solution | 17 lbs. | 0.0150 | 0.26 |
| Mix 1 minute | | | |
| Sodium Silicate "N" grade | 32 lbs. | 0.0200 | 0.64 |
| Pentachlorophenol | 3¾ lbs. | 0.2100 | 0.79 |
| Mix 5 minutes | | | |
| Total | 530¾ lbs. | | $11.45 |
| Cost/lb. | | | $ 0.0216 |
| Average Spread | | | 80 lb/MDGL |
| Cost/MDGL | | | $ 1.73 |
| Cost+20% Waste | | | $ 2.08 |

Table 3.—COMPARISON OF LOWER SHIPPING WEIGHTS DUE TO LOWER PANEL MOISTURE CONTENT

| Adhesive | Approx. amount of water added as a result of the adhesive, 3/8-inch basis, pounds | Pressing cycle 3/8-inch, 2 PPO* | Approx. Wt/M, 3/8-inch basis, pounds | Panel moisture content, percent |
|---|---|---|---|---|
| Exterior Phenolic | 34 | 4 min. @ 270° F. | 985 | 5–6 |
| Protein | 58 | 3¼ min. @ 270° F. | 1,015 | 8–9 |

* Panels per opening in the hot press.

**Blood/Soya Hot-Press Adhesives:** Blood/soya adhesives are manufactured from soluble animal blood, ground soybean meal, filler of various kinds, and chemicals for viscosity control and "crosslinking." These ingredients are blended in large batches and packaged in 80- or 85-pound bags. The blood/soya interior adhesive is mixed in the mill by combining the blended "adhesive powder" with water to form a low-viscosity solution. To this solution is added lime, caustic soda, and sodium silicate to form the completed mix. Blood/soya adhesives are rather high in viscosity and appear dark brown in color. The final glue mix is then pumped to the holding tank ready for use in assembling plywood panels.

Blood/soya glues are not naturally mold resistant so a toxic agent is necessary in the glue to preclude delamination of the plywood panel due to mold and organism, or both, attack upon the glue line. Mold resistance can be achieved in two ways. The addition of pentachlorophenol is a common method. The addition of small quantities of phenolic resins is also a satisfactory method to achieve toxicity. Resin additions have the added feature of water resistance in increasing glue-line quality.

## Comparison of Interior Hot-Press Adhesives

Blood/soya and interior phenolic adhesives both accomplish the same purpose. They are capable of producing high quality glue bonds necessary to pass Commercial Standards for interior Douglas-fir plywood. Although the adhesives do the same job, they are somewhat dissimilar in nature, appearance, handling qualities, conditions of use, advantages, and ultimate bond quality.

**Advantages of Blood/Soya Over Phenolic Adhesives:** Probably the most prominent advantage of blood/soya glues is the lower glue-line cost. A saving of from $0.20 per thousand square feet double glue line (MDGL) to $1.60 MDGL is possible by use of protein adhesive in preference to phenolic resin bonding agents. A summary of glue-line costs appears in Table 1. Typical glue-line cost calculations for protein and phenolic mixes appear in Table 2.

Veneer can be dried to a higher moisture content for hot-press protein gluing, since protein adhesives can tolerate and require higher moisture content veneer. It is possible to increase the dryer capacity of a mill by several percent. This advantage may not be realized, however, if a mill does not segregate veneer for exterior plywood production and interior protein production.

Mixing times are necessarily shorter for protein glues. This would allow about twice as much glue to be mixed in a given length of time, allowing more spreaders to be operated from a single glue mixer.

Press time for hot-press protein glues are about one-half to two-thirds that of phenolic glues. This is true since the mechanism of adhesive curing is essentially different. In the case of protein glues, the adhesive cures as a result of the formation of insoluble "cross-linked" proteinate compounds. This reaction is fairly rapid at an inner glue-line temperature of from 170° to 200° F. Phenolic resins cure by polymerization and condensation of the resin mass. This reaction is rather slow in the range of inner glue-line temperature (IGLT) of from 170° to 200° F. therefore the press time must be lengthened to obtain IGLT's of about 220° to 250° F.

**Advantages of Furafil-Extended Phenolic Adhesives Over Blood/Soya Glue:** Both protein interior and phenolic interior adhesives will pass standards necessary for interior plywood. It is generally assumed, however, that phenolic resin interior glues are far superior in bond quality. In this respect, phenolic interior has a definite advantage, and chances are that plywood made with phenolic interior will sell for a higher price than blood/soya-bonded panels. The figure shows a comparison of average boil test wood failure results on protein and phenolic interior bonded panels. Properly formulated protein glues and interior phenolic glues would pass the Commercial Standards cyclic cold soak test. As can be seen in the figure, the phenolic interior adhesives have a definite advantage over the more stringent Commercial Standards cyclic boil test.

Protein interior glues have a pot life of from about 3 to 4 hours at normal temperatures. As opposed, phenolic interior glues have been used successfully a week or two after mixing. A mill using an all-resin operation, as in Canada, could mix glue on one shift to provide glue for three shifts. This is not possible using blood/soya adhesives. Also, in the event of equipment breakdowns, phenolic adhesives do not have to be pumped to the sewer and wasted, as is often the case with blood/soya when the pot life tolerance is exceeded.

If frequent changes from exterior to interior glue are common on the same spreader, less "down time" results in an all-resin operation. This is obtained by not requiring the alteration of the hot-press temperature and not having to always wash the glue spreaders. With protein glues, it is necessary to wash the spreaders and glue transfer lines thoroughly before using exterior glues. "Down time" can quickly alter a mill's production capacity.

Another advantage is lower shipping weights due to lower panel moisture content. A comparison is shown by Table 3.

A saving in shipping weight is theoretically possible because of the lower average panel moisture content of phenolic bonded panels.

Phenolic resin bonded plywood, characteristically, can tolerate almost twice the closed assembly time as compared to protein glues. In the majority of mills this advantage may not be realized. Longer assembly time tolerance can be utilized, however, to give added "safety factor" to insure the adhesive does not dry out on the core veneers.

## Summary

A resumé of interior gluing and a brief comparison of hot-press interior adhesives is presented. Most mills currently utilize the lower-cost blood/soya glues for making interior plywood. In the last few years this has been necessary, since market conditions have been rather competitive. In the future, one might expect to observe a switch to phenolic-interior or even all-exterior phenolics. Competition from other building materials and a need for better quality plywood may force the manufacturer into using adhesives that are more tolerant of moisture. This has been the history of gluing in the softwood plywood industry—higher quality glue bonds.

***UTILIZATION OF:***

# Aspen Wood Residues[1]

D. W. STRANKS

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**Fermentation studies with aspen wood and Ruminococcus flavefaciens a cellulolytic microorganism from the rumen of cattle, show that aspen can be fermented after a mild pretreatment. High lignin content does not appear to inhibit the fermentation, rather the close association of lignin and cellulose, DP and degree of crystallinity are responsible.**

THE CANADIAN WOOD INDUSTRY has long sought ways to profitably use the vast quantities of wood residues which annually accumulate on plant premises. The finely divided residues, sawdust, and wood flour have been the most difficult to utilize. Some of this material has been used for production of plant steam, electrical power, and domestic fuel, but the more extensive use of natural gas is now replacing these residues as fuel. Admixed with chemicals, it has been used as a soil conditioner. Charcoal briquets are now being made from sawdust residues, and some of this material is used in the manufacture of cleaning compounds. The plastic industry is also making use of these residues, particularly the finer material. However, the current utilization practices do not absorb major portions of the residues. Research is required to find new means for profitable utilization. Industrial fermentation could be one method. The carbohydrate content of this wood material is a potential source of cheap substrate. Attempts to ferment wood residues gainfully have been few, largely because of the general inactivity observed when employed for substrate purposes.

Early workers claimed that heavy lignification was responsible for the non-fermentability usually observed where fermentation of the wood holocellulose fraction was tried. More recent studies by Virtanen and others (1, 2), Hajny and others (3), and Lawton and others (4) imply that the lignin itself is not inhibitory but suggest the lignin is combined with holocellulose and the type of linkage inhibits fermentation of the holocellulose. Freudenberg (5) and wood chemists generally are more and more convinced that some chemical link does exist between lignin and holocellulose, and recent work at the Ottawa Laboratory, Forest Products Research Branch strengthens these arguments. High energy irradiation of wood is known to increase its fermentability. A review by Mater (6) suggests that one effect of high energy irradiation is the breaking of these postulated lignin cellulose bonds. The lateral bonds of crystalline cellulose may also be split by this treatment. Irradiation is also known to depolymerize (lower the DP) the cellulose of wood. In a preliminary study by the author (7) pretreatment, which lowered DP, was considered to render wood species more susceptible to fermentation. Relatively few studies have been undertaken in this field but continued study will probably show that the lignin cellulose linkage, DP, and crystallinity of the holocellulose all in some degree inhibit fermentability in untreated wood.

In a further attempt to utilize the holocellulose content of wood residues by fermentation, aspen sawdust only was used for test. The immediate object of study was to determine the minimum of treatment required to render wood fermentable by a rumen bacterium. Data obtained with such an organism could be applied to the problems of wood utilization for cattle fodder and to studies of substrates for fermentation. In this study it was also anticipated that further information might be obtained as to the factor(s) in untreated wood residues which inhibit fermentation of the natural material.

## Materials and Methods

The test organism *Ruminococcus flavefaciens* was isolated from fresh rumen ingesta using a modification of Hungate's technique (8). The organism appears to be similar to that described by Sijpesteijn (9). This organism has been maintained in liquid culture and also in freeze-dried condition for 7 years. For inoculation purposes, the organism was grown on No. 1 Whatman filter paper cellulose strips in medium containing 80 percent rumen fluid and inorganic salts, as advocated by Hungate.

Aspen, *Populus tremuloides* Michx. was used for all fermentation tests. This wood was milled in a Wiley mill and the 40 to 60 mesh fraction screened out for test use. Finer (100 to 200 mesh) material was used for one test. Pulping and semi-pulping of the wood was carried out at from 70° to 80°C. under conditions of continuous stirring, using analytical grade sodium chlorite and sodium hydroxide reagent. Alkali cooking was done at

The Author: D. W. Stranks has a B. A. from McMaster University and M. Sc. from McGill University. He joined the Microbiology Unit of the FPL of Canada in 1950 after 2 years at the Fermentation Pilot Plant of the National Research Council of Canada.

[1] Presented at Session XV, Division 4, Chemical Conversion, 15th Annual Meeting of FPRS, Louisville, Ky., June 22, 1961.



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15 psi for one-half hour; the liquor to wood ratio was 10:1. After each treatment the wood was washed well with water, air dried, and 20 grams weighed out for test. The control samples of so-called "untreated" wood were cooked with water for 20 minutes at 15 psi, then washed well to remove colloidal matter that would not settle readily. The latter caused error because of mechanical carry-over into the overflow receiver of the fermentation apparatus.

Upon completion of a fermentation test, the wood substrate remaining was removed quantitatively from the fermenter, washed well with water, then acetone, and air-dried. The loss in weight due to fermentation was corrected for moisture content, and recorded.

Standard methods of wood analysis were used to determine holocellulose (10), alpha and hemicellulose (11), and lignin (12) of both the treated wood samples and the fermented residues.

The organic acid end-products of fermentation were determined by using Neish's (13) method. All effluent and medium remaining in the fermenter after fermentation was combined and an 800 milliliter aliquot used for test.

The medium used for starting a fermentation in the fermenter was comprised of 50 percent rumen fluid (centrifuged at 26,000 rpm for 30 minutes to clarify), 0.1 percent yeast extract, 0.1 percent peptone, 0.3 percent sodium bicarbonate, inorganic salts according to Hungate (8), 0.05 percent cellobiose and 5 milliliters of a 10 percent solution of sodium thioglycolate added aseptically after sterilization. The medium was prepared and sterilized in a 2-liter Erlenmeyer flask fitted with a cotton plug. When removed from the autoclave, and while still hot, the medium was gassed aseptically using oxygen-free carbon dioxide. Gassing was continued until the medium reached from 40° to 50°C. One liter of medium was prepared, inoculated with 20 milliliters of culture medium and then added to the fermenter. The substrate for test was weighed into the fermenter and sterilized with it. After an initial 48-hour incubation period to give the organism opportunity to increase in numbers, addition of fresh medium was begun. This medium was identical to that in the fermenter except for the reducing agent which was omitted. Six liters of this medium was prepared, sterilized and gassed until cool, using the same technique of anaerobiosis used for preparing fermenter medium.

### Fermentation Procedure

Cellulose decomposing bacteria generally decompose only small quantities of substrate, in the order of from 0.1 to 0.5 gram substrate per 100 mililiters of medium after which fermentation ceases. This is especially true with pure cultures and with the *Ruminococcus flavefaciens*. To allow fermentation of 20 grams or more substrate without having to try initiating fermentation in very large volumes of medium, a special fermenter was devised. In principle the apparatus is a continuous culture-type fermenter. However, in this instance the substrate, which is insoluble, was retained in the fermenter and fresh medium was continually circulated past it. Toxic substances and end-products causing early stoppage of fermentation were continually removed and the substrate therefore fermented to completion or near completion.

The fermentation apparatus is seen in the diagram. Continuous fermentation was achieved by periodically pumping fresh medium into the 2⅜-inch diameter cone-shaped fermenter from the feed reservoir via the pump and feed system. Stale, used medium overflowed from the fermenter into a holding vessel which was drained when required. Substrate, being insoluble, was retained by the settling device of the fermenter and was not carried over into the overflow receiver. The settling tube was sealed inside the fermenter as shown. The fermenter was made in two sections and joined by a flange joint to facilitate cleaning and to provide means for holding the rubber diaphragm necessary to the proper function of the settling tube. The rubber diaphragm was cut from 3/16-inch rubber and mounted 3/16 inch below the bottom outlet of the settling tube. When the diaphragm was correctly placed as indicated, substrate particles settled out in the tube and collected on the diaphragm. Stirring action returned them to the fermenter but did not disturb particles settling in the tube. No carry-over of substrate particles to the overflow reservoir was observed. Both stirring and anaerobiosis was achieved by means of a stream of oxygen-free carbon dioxide piped to the bottom of the fermenter. The gas stream directed into the cone-shaped base of the fermenter provided excellent stirring over the entire 18-inch liquid depth of the unit. A glass fibre filter was placed at the entrance to the fermenter as a deterrent to contamination and to provide a steadying element for the long gassing tube. All gas supplied to the fermenter was first passed through a filter designed to remove oil fumes, then through a large sterile glass fibre filter and finally through the smaller filters as shown.

Above the fermenter the reservoir for holding fresh medium was installed. The reservoir was piped through a constant head chamber and Maisch metering pump to the fermenter as shown. The chamber maintained a constant head at the pump regardless of the liquid level in the reservoir. A small volume of gas was run through the head chamber to maintain anaerobic conditions in the feed medium. The pump was wired to an interval timer set to deliver an aliquot of fresh medium to the fermenter every 15 minutes. Pumping rate was adjusted to give a complete change of medium every 24 hours. The whole feed reservoir system was plumbed with glass and neoprene tubing and was sterilized in entirety before use.

The overflow receiver was mounted close to the fermenter and connected to it with neoprene tubing. A drain tube and pinch cock placed on the bottom of the receiver facilitated removal of stale effluent. Mercuric chloride solution was added to the receiver to stop all further occurrence of enzyme activity. Effluent was refrigerated when removed from the receiver until required for analyses.

It was found convenient to mount the entire fermentation apparatus upon a rack fitted with a wooden base and casters, and to roll the apparatus in and out of a walk-in incubator which was held at 39° C. All components of the apparatus were first sterilized one-half hour at 15 psi, then assembled on the rack and the necessary joining of component parts made aseptically using a gas flame. The fermenter was gassed out before addition of the medium. Fermenter medium was added aseptically by removing the large stopper at the top of the fermenter.

The fermentation apparatus described allowed fermentation of 20-gram test samples. Although relatively large volumes of medium were required for each test, the fermentation proper was carried out in a volume of one liter. Batch-wise fermentation would necessitate trying to initiate activity in volumes of 6 to 8 liters with only 20 grams of insoluble substrate. This is not easily accomplished; in one successful instance, less total activity was observed than found with the continuous type method. A similar system using larger volumes and larger test samples is to be desired since well-

Table 1.—UTILIZATION OF ASPEN BY FERMENTATION*

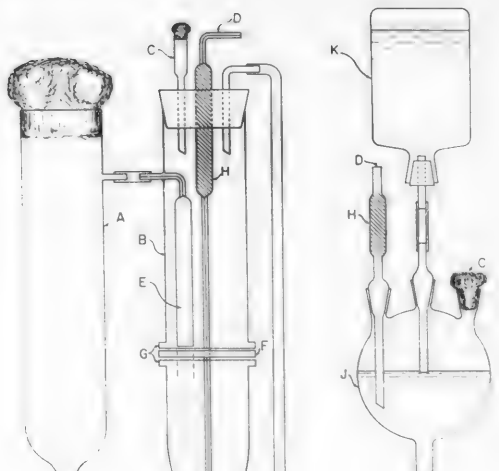
| Treatment | Weight Loss | Lignin Before Fermentation | Lignin After Fermentation | Apparent Loss of Lignin | Utilization of Holocellulose by Calculation |
|---|---|---|---|---|---|
| Untreated | 17.0 | | | | |
| Untreated | 14.0 | 21.01 | 18.35 | 2.66 | 11.3 |
| Untreated (100–200 mesh) | 12.1 | | | | |
| Chlorite (90%) | 85.5 | | | | |
| Chlorite (90%) | 77.0 | 2.51 | 0.36 | 2.15 | 74.9 |
| Chlorite (30%) | 64.4 | 10.15 | 4.99 | 5.16 | 59.2 |
| Chlorite (30% | 67.6 | 6.43 | 1.74 | 4.69 | 62.9 |
| Alkali (80%) | 36.9 | 21.15 | 18.46 | 2.69 | 34.2 |
| Chlorite (15%) Alkali (10%) | 78.5 | 9.35 | 4.30 | 5.05 | 73.5 |
| Chlorite (8%) Alkali (5%) | 61.3 | 15.76 | 9.58 | 6.18 | 55.1 |

*Values expressed as percent treated wood fed to fermenter.

Table 2.—UTILIZATION OF HOLOCELLULOSE*

| Treatment | Holocellulose Original | Residual | Utilized | Utilization of Holocellulose† |
|---|---|---|---|---|
| Untreated | 88.03 | 73.53 | 14.5 | 11.3 |
| Chlorite (30%) | 93.53 | 30.15 | 63.4 | 62.9 |
| Chlorite (15%) Alkali (10%) | 90.37 | 17.28 | 73.1 | 73.5 |
| Chlorite (8%) Alkali (5%) | 86.17 | 30.08 | 56.1 | 55.1 |

*Values expressed as percent of treated wood fed to the fermenter.
†As in Table 1.




Continuous feed fermentation apparatus for testing fermentability of wood residues. A, overflow reservoir; B, fermentation vessel; C, gas-outlet; D, gas inlet; E, settling tube; F, rubber diaphragm; G, flange joint. H, glass fibre filter; I, pump. J, constant head feed chamber; and K, feed reservoir.

fermented samples left too little residue for adequate analyses. A larger apparatus is therefore contemplated to ferment samples of 70 grams or more. Stirring action was adequate in the above apparatus but a mechanical motor-driven stirrer is probably more advantageous to keep the insoluble substrate submerged in the medium, and it would require less carbon dioxide. The settling tube device proved to be superior to any filter system for retaining substrate in the fermenter. All filter systems tried invariably clogged and blocked up during the incubation period, whereas, no difficulty was observed with the system described. The whole system, while in use, ran without difficulty and required a minimum of attention.

## Results and Discussion

Twelve fermentations were carried out using the apparatus described and 20-gram samples for test in an effort to determine the effect of pulping pretreatments on fermentability. Two runs were discounted; one because contamination crept in and the other because of mechanical failure. The remaining 10 runs ran smoothly and required little attention during the 8 to 11 day incubation period. The loss in wood weight resulting from fermentation, the type of wood treatment used before fermentation, and lignin content of the wood as observed before and after fermentation are all listed in Table 1. Untreated aspen showed a loss in weight of from 14 to 17 percent. Better fermentation was not obtained with finer mesh material, contrary to expectation. Fully pulped aspen, treated with 90 percent chlorite showed from 77 to 85 percent weight loss, whereas, semi-pulped material treated with 30 percent chlorite showed from 64 to 67 percent loss in weight. Alkali cooking alone improved fermentability somewhat but was most effective when combined with chlorite treatment. Aspen, treated with 15 percent chlorite and 10 percent alkali, showed similar weight loss to fully pulped material even though the lignin content was 9 percent. Reducing the chlorite and alkali to 8 and 5 percent respectively showed a weight loss of 61 percent; the lignin content in this case was almost 16 percent. Apparently high lignin content does not deter fermentation.

Lignin analyses of the treated wood and the residual material after fermentation showed that an apparent loss of lignin occurred during fermentation. A simple test with fermenter medium and treated wood showed that no loss occurred due to the solvent action of fermenter medium. Bacterial action must have decomposed the lignin, or at least freed from the holocellulose, and imparted it to the medium. Since there is no evidence to show that *Ruminicoccus flavefaciens* utilizes lignin, it was assumed that lignin was released to the medium. Based on this assumption, lignin lost to the medium was considered to be part of the residue left after fermentation, and figures for utilization of the wood holocellulose were calculated accordingly. These are shown also in Table 1.

Treated wood and residual material were analyzed for holocellulose content for four of the runs. The values obtained and the loss due to fermentation are shown in Table 2. The data for holocellulose utilization in these runs compare favorably with the calculated values of Table 1 and therefore the assumption made regarding the non-utilization of lignin can be considered correct. The holocellulose fractions were analyzed for alpha and hemicellulose content. The data obtained are shown in Table 3. From this, one can observe some of the effect of pretreatment of the wood. As expected, the 30 percent chlorite-treated material was higher in alpha and hemicellulose content. The 15 per-

cent chlorite, 10 percent alkali-treated wood was highest in alpha but lowest in hemicellulose. The lesser chlorite-alkali-treated material was similar to the 30 percent chlorite-treated material in alpha and hemicellulose content. Optimum treatment probably requires alkali sufficient to solubilize chlorolignins formed, yet not enough to destroy the hemicellulose fraction, and sufficient chlorite or chlorine dioxide to effect change in the lignin so that the organism can free lignin to the medium and utilize the holocellulose. These values must lie between 8 to 15 percent chlorite and 5 to 10 percent alkali, based on the weight of wood. The values for hemicelluloses for untreated material in Table 3 are interesting in that a gain in hemicellulose content occurred due to fermentation. Alpha cellulose is probably hydrolyzed by enzyme action yielding material which analyzes as hemicellulose, and which shows that the organism probably metabolizes alpha cellulose progressively. In every case where wood was pretreated, both alpha and hemicellulose were utilized. Table 4 shows the extent to which these fractions were utilized. Where wood was treated with 15 percent chlorite and 10 percent alkali, alpha and hemicellulose fractions were most extensively utilized and equally well; even though less hemicellulose was originally present. The least chlorite-alkali-treated wood gave similar holocellulose utilization to that with 30 percent chlorite treated wood. However, more extensive alpha cellulose and less hemicellulose utilization was obtained.

Attempts to determine the yield of acidic end-products produced by fermentation have not been too successful The high dilution of products in the relatively large amount of effluent made accurate determinations difficult. However, an ether extract of 800 milliliters effluent from the run where 15 percent chlorite, 10 percent alkali-treated wood was used gave values for acids produced as shown in Table 5. The total values obtained were corrected for acids in the rumen fluid added as part of the medium. The figures obtained show that the two major products of fermentation were succinic acid and acetic acid, 43 and 46 percent, respectively, of the total acid produced. A small amount of propionic and formic acids was also produced. Approximately 64 percent of the holocellulose fermented was converted to acid products. Approximately 42 percent of the treated material fed to the fermenter was converted to the acids shown. No other products of fermentation have been identified as yet. A yellow to orange pigmented material invariably was found adsorbed to the residual substrate following fermentation. This material is probably a flavin type substance. It was somewhat soluble in acetone and appeared to be light-sensitive.

This study has shown that aspen will ferment well when pretreated with the pulping agent sodium chlorite, but complete pulping is not required. Partially pulped aspen with lignin content just under 16 percent was 55 percent utilized. Since this high lignin content did not adversely affect fermentation, it is reasonable to suggest that the lignin holocellulose inter-relationship rather than lignin concentration is partly responsible for lack of fermentability of untreated wood. However, it is conceivable that natural lignin may be toxic and the pretreatment using chlorite and alkali changed the lignin sufficiently to render it non-toxic. The fact that considerable lignin was lost to the medium as a result of fermentation suggests that the organism endeavors to free the holocellulose of lignin by enzyme action before actually decomposing the holocellulose. The pretreatment probably breaks linkages that this organism is not capable of, after which the organism can break the final linkage, free the lignin and metabolize the holocellulose. Not just chlorite or chlorine dioxide treatment but alkali cooking appears to be an essential element of the dual treatment. The alkali dissolves out chlorolignins formed by chlorite treatment, but at the same time probably lowers the DP of the holocellulose, and may have some small effect toward decreasing the crystallinity of the cellulose structure. Much more intimate study of the effect of treatment is required to accurately assess the complexity in untreated wood which resists fermentation.

Further study may reveal that the total chemical requirement necessary for fermentability can be reduced below that observed in this study Chlorine, for example, could be used to liberate chlorine dioxide from chlorite and the mixture used for treatment. A saving in total chemical may result. This has been observed when chlorine dioxide is prepared by this means for pulp bleaching purposes. The total gaseous chlorine dioxide required to give the same effect produced by treatment with 8 percent chlorite is calculated to be approximately 5 percent free gas based on the wood. This can be derived using the equation $5\ NaCL_2 + 4HCL \longrightarrow 4CLO_5 + 5NaCL + 2H_20$. The figure of 5 percent chlorine dioxide is too high a value to be practical. It represents a value five times that required normally for bleaching pulp in the paper industry. Better methods of reacting the gas with the wood or multiple treatment using low concentrations of acid, alkali, and chloride dioxide might result in a lower gas requirement.

**Table 3.—UTILIZATION OF ALPHA AND HEMICELLULOSE***

| Treatment | Alpha Cellulose | | | Hemicellulose | | |
|---|---|---|---|---|---|---|
| | Original | Residual | Utilized | Original | Residual | Utilized |
| Untreated | 52.33 | 42.51 | 9.82 | 25.70 | 26.63 | + 0.93 |
| Chlorite (30%) | 55.10 | 20.67 | 34.43 | 36.25 | 9.32 | 26.93 |
| Chlorite (15%) Alkali (10%) | 67.87 | 12.83 | 55.04 | 20.96 | 3.76 | 17.20 |
| Chlorite (8%) Alkali (5%) | 56.89 | 18.68 | 38.21 | 26.56 | 10.50 | 16.06 |

*Values expressed as percent treated wood fed to the fermenter.

**Table 4.—UTILIZATION OF HOLO ALPHA AND HEMICELLULOSE***

| Treatment | Holocellulose | Alpha Cellulose | Hemicellulose A and B |
|---|---|---|---|
| Untreated | 16.47 | 18.77 | + 3.62 |
| Chlorite (30%) | 67.90 | 62.49 | 74.29 |
| Chlorite (15%) Alkali (10%) | 80.90 | 81.10 | 82.06 |
| Chlorite (8%) Alkali (5%) | 65.09 | 67.16 | 60.47 |

*Values expressed as percent of each substance fed to the fermenter.

**Table 5.—ACIDS PRODUCED BY FERMENTATION OF 19.1 GRAMS OVEN-DRIED ASPEN PRETREATED WITH 15 PERCENT CHLORITE AND 10 PERCENT ALKALI***

| Acids | Total Acid, grams | Total Acid Corrected for Acids Added as Rumen Fluid, grams | Acid produced, Percent of Total Acid |
|---|---|---|---|
| Butyric | 2.85 | none | none |
| Propionic | 2.87 | 0.48 | 5.96 |
| Acetic | 12.82 | 3.46 | 42.98 |
| Formic | 1.64 | 0.39 | 4.84 |
| Succinic | 3.72 | 3.72 | 46.21 |
| Total | ----- | 8.05 | 99.99 |
| Consumed holocellulose converted to acids | | 63.8% | |
| Treated material converted to acids | | 41.9% | |
| Aspen sawdust converted to acids (15% loss due to treatment) | | 36.4% | |

*Holocellulose utilization was 73.1 percent.

If a lower chemical requirement was found possible, one immediate application might be to test the usefulness of treated wood as cattle fodder. As fodder, the treated material would be metabolized by a mixed milieu in the ruminant stomach in contrast to the pure culture used for test here, a lesser treatment may be all that is necessary to give the same or better utilization. It is interesting to compare the digestibility by cattle of average quality hay (55 to 58 percent utilized) and high quality hay (65 to 67 percent utilized) with the fermentability of aspen found in this study. The lighter chlorite-alkali-treated material compares favorably with average quality hay while the heavier chlorite-alkali-treated material was more digestible than high quality hay. The value of such a comparison is limited however, since different methods were used to obtain the figures for hay and wood. Only a complete feeding study would show the usefulness of treated wood as fodder. Problems of energy loss through mastication, palatability, and treatment costs would all have to be resolved. Where attempts have been made to use finely divided wood residues for fodder cellulose, complete or almost complete delignification of the material was required to obtain good digestibility (14). Leibscher (15) found that fully delignified spruce sulfite pulp was 83.8 percent digestible, whereas untreated spruce sawdust was only 11.9 percent digested. If the sawdust was given a cold alkali treatment, only a slight improvement, 16.9 percent digestibility, was obtained. Similar results were observed with cereal straws (16). Figures for digestibility were not given but apparently complete delignification of the materials was required to obtain a suitable fodder. More study aimed at partial delignification using chlorine dioxide and alkali treatment as outlined above but contingent upon the economy of treatment and the results of feeding trials might possibly result in the formulation of an acceptable fodder cellulose. Gainful utilization of wood residues would also be achieved.

Large-scale fermentation work using this organism and aspen residues as substrate would be pointless and difficult to accomplish at this time. The tremendous volumes of medium necessary for fermentation of any large quantity of material makes any such study prohibitive. Several important factors must be studied first. One is to determine the cause for early stoppage of fermentation after not more than 0.5 gram substrate per 100 milliliters of medium has been utilized. The nutritional factors found in rumen fluid to be essential for successful propagation of the organism must be determined so that a suitable synthetic medium could be formulated for large-scale work. All aspects of wood pretreatment must be studied to find the most economical type. If and when these problems are resolved large-scale fermentations might be worthwhile. The end-product yield results are interesting because more than 60 percent of the holocellulose utilized was converted to useful acid substances. This value is of the same order or higher than for the better industrial fermentations. The 73 percent utilization of holocellulose observed was of the same order as that obtained by Hajny (3) for sweet gum, using thermophilic organisms for test, and higher than that obtained by Virtanen (1) when fermenting wood dusts. The conversion of holocellulose to acid products which was 63 percent, was higher than found by Hajny (50 percent). This could be explained by the differences in fermentation mechanism of the test organism. The *Ruminococcus* culture was found to produce little gas which probably results in the conversion of more material to acids. The acid produced, in percent of the wood, was also slightly higher than Hajny obtained for his best fermentations of sweet gum. Further study may resolve the numerous problems encountered in the fermentation of wood residues, and possibly in time to arrive at a useful industrial fermentation.

This study was necessarily limited in scope. Only one aspect of wood pretreatment, namely, chemical pretreatment was investigated. Only one pulping agent was tried. The pretreatments that could be tried are many and varied, i.e., pressure, radiation, ultrasonic, disruption, predigestion with wood-rotting fungi, to mention just a few. It is lamintable that so little study has been undertaken when such a yast potential in raw materials exists. It is hoped that other workers will be directed toward this neglected field of study and that in the future, a useful process for the microbiological utilization of wood residues will become a reality.

### *What This Research Means*

The use of wood residues for fuel, soil conditioners, charcoal, plastics, etc., merely scratches the surface of the vast amounts of raw material available. We need new means of profitable utilization—industrial fermentation could be one such method. Complete utilization of the carbohydrate fraction could lead to industrial fermentations of wood to produce useful chemicals, and fermentable residues could be used as a major portion of cattle feed.

Acid hydrolysis of wood residues to wood sugars with subsequent fermentation to useful products requires expensive equipment and the sugars must compete favorably with sugars obtained from agricultural sources. A second approach is to use specific organisms capable of fermenting wood residues directly.

Although limited in scope, research reported here indicates possible lines to follow in this neglected field of study. And it gives hope that, in the future, a useful process for the microbiological utilization of wood residues will become a reality.

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***VARYING MOISTURE CONTENT OF:***

# Mechanically Dried Veneers[1]

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Fig. 1. The veneer dryer used at the Forest Products Research Laboratory, Princes Risborough, England, for determining the drying characteristics of species.

IN THE MANUFACTURE OF PLYWOOD, selected logs are cut into convenient lengths, mounted in a lathe, and peeled into veneer. The thickness of the veneer can usually be varied from a few one-thousandths of an inch to as much as 0.25 inch but, in practice, veneers under 0.032 inch are rarely produced and the upper limit is about 0.125 inch. In the second stage of the process, the green veneers are slipped into convenient sizes and dried, usually in mechanical dryers. The object of the drying is to reduce the moisture content of the wood to a level consistent with the requirements of the adhesive used to bond the veneers together and related to the equilibrium moisture content of the environment in which the plywood will be exposed after bonding. Moisture changes between the manufacture and the use of the plywood are thus avoided, and the danger of distortion minimized.

Ideally, therefore, the veneers should leave the drying machine at one uniform pre-selected moisture content which may be a compromise if the requirements of the adhesive and of the exposure environment are different. In practice, however, this ideal is difficult to attain because of differences in the initial moisture contents and in the drying rates of the veneers themselves. The material emerges from the dryer, probably at the correct average moisture content, but with a considerable spread above and below the mean value.

**Variation in moisture content decreases when dried veneers are stored in piles and natural conditioning takes place. But the process is a slow one, and weeks rather than days are necessary. An alternative method is to force-condition the individual veneers in a suitably designed chamber. Small scale tests indicated that a uniform moisture content could be obtained in minutes rather than hours by this method.**

## Moisture Content Data

Over the past decade the Forest Products Research Laboratory has examined the suitability of some 65 species for plywood manufacture. The tests were all carried out in the Laboratory's plywood plant, which is capable of converting logs into 5-foot square plywood, and the procedure included an evaluation of the species at all stages in the manufacturing process (1)[2]. Of the timbers dealt with, some were well known to the British plywood industry, and these have been used to provide a basis for comparison. Other species were new for plywood and have been tested at the request of various overseas forest departments or of individual suppliers.

As part of these trials, the drying charactertistics of 0.064-inch and 0.125-inch thick veneers of each species were determined in the labora-

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[2] Numbers in parentheses refer to Literature Cited at the end of this report.

tory's commercial-size platen dryer shown in Figure 1. The three-deck machine is 10 feet wide and has an 8 foot long infeed table, a 15 foot drying section and a 10 foot long cooling chamber in which room temperature air is passed over the hot veneer and exhausted outside the building. In the drying section, rows of platens, steam heated to 170°C. (133°F.) effect the drying of the veneer as it is carried through the machine on rollers. During the drying of each species, one or more sets of three 5 foot by 2 foot sheets were taken, at random, from each batch of freshly dried veneers and five 6-inch squares were cut immediately from along a diagonal of each sheet, yielding a total of fifteen 6-inch squares. The moisture content of these squares was then determined by either of two machines specially developed for this purpose. The Naiad (2), shown in use in Figure 1, utilizes infrared heating for removal of moisture while the Platen-oven (3), shown in Figure 2, employs the same principle as the dryer itself, except that the two platens are heated electrically to 200°C. (392°F). The output of the Naiad is 40 estimations per hour while that of the Platen-oven is dependent on veneer thickness, 1 estimation being obtained every 1.2 minutes, with 0.064-inch thick veneers and every 2.4 minutes with 1.125-inch material. The moisture content data obtained from these machines were expressed as "Average," the mean moisture content of the fifteen 6-inch squares; "Sheet Average," the mean of the 5 moisture contents in each 5 foot by 2 foot sheet (the maximum and minimum are the highest and lowest of the three "sheet averages"); or "Spread", the maximum and minimum moisture content from the fifteen 6-inch squares.

These figures were used, primarily, to control the drying process and to provide data for an assessment of the drying characteristics of each species. Over the years, however, these routine measurements have accumulated and can now form the basis for a general assessment of the variation in moisture content of freshly dried veneers.

## Moisture Content Analysis

Tests (4) with freshly dried veneer, 0.064-inch and 0.125-inch thick, showed that the variation in moisture content was not affected by the veneer thickness, the drying time, or by any of the machine settings. The species of the veneer, on the other hand, had some effect on the moisture content variations and three groups could be recognized, *viz.* those species with a) less than normal, b) normal, and c) greater than normal moisture content variation.

The results of this assessment are given in Tables 1a, 1b, and 1c. The rating of each species is based on a consideration of the "sheet average" and "spread" data and the overall assessment is thus qualitative rather than precise in nature. Of the 65 species considered, 42 have a "normal" variation in moisture content, 7 are "greater than normal," and 16 "less than normal." It should be emphasized, however, that differences between the three groups are small, and considerable moisture content variations occur even in the "less than normal" species.

The second stage in the analysis was to determine, irrespective of species, the variation in moisture content which could be expected in freshly dried veneer. The data at each "average" moisture content were examined, therefore, and limits calculated within which 99 percent of the samples lie. These limits are expressed in Figure 3, and thus provide an indication of the maximum variation which can occur with any species. The variation in moisture content generally increases with the "average," and since the "spread" limits are wider than the "sheet average," it would seem that wet patches are more common than entirely wet veneers. The effect of these wet patches must be considered from two aspects. First, if the moisture content of the wet patches exceeds 20 percent for any length of time, then there is a danger of mold growth

**Table 1a.—SPECIES WITH A "LESS THAN NORMAL" MOISTURE CONTENT VARIATION**

| Common name | Botanical name | Density* | Origin of the timber |
|---|---|---|---|
| Gaboon | Aucoumea klaineana | 27 | W. Africa |
| Agba | Gossweilerodendron balsamiferum | 32 | Nigeria |
| Hog plum | Spondias mombin | 34 | Jamaica |
| Yellow seraya | Shorea faguetiana | 35 | N. Borneo |
| Sapele | Entandrophragma cylindricum | 39 | Ghana |
| Ramin | Gonystylus bancanus | 41 | Sarawak |
| Kurokai | Protium decandrum | 41 | British Guiana |
| Pterygota | Pterygota bequaertii | 41 | Nigeria |
| Serette | Byrsonima coriacea var spicata | 45 | Trinidad |
| Danta | Cistanthera papaverifera | 46 | Ghana |
| Kapur | Nesogordonia lanceolata | 48 | N. Borneo |
| Pillarwood | Cassipourea malosana | 48 | Tanganyika |
| Keruing | Dipterocarpus sp. | 49 | N. Borneo |
| Afzelia | Afzelia spp. | 49 | Nigeria |
| Greenheart | Ocotea rodiaei | 64 | British Guiana |

* Pound per cubic foot at 12 percent moisture content.

**Table 1c.—SPECIES WITH A "GREATER THAN NORMAL" MOISTURE CONTENT VARIATION**

| Common name | Botanical name | Density | Origin of the timber |
|---|---|---|---|
| Ceiba | Ceiba pentandra | 22 | Ghana |
| Light red seraya | Shorea parvifolia | 28 | N. Borneo |
| Ogea | Daniellia spp. | 30 | W. Africa |
| Ilomba | Pycnanthus angolensis | 32 | Nigeria |
| Scots pine | Pinus sylvestris | 32 | England |
| Chile pine | Araucaria araucana | 34 | Chile |
| Maho | Sterculia pruriens | 36 | British Guiana |

**Table 1b.—SPECIES WITH A "NORMAL" MOISTURE CONTENT VARIATION**

| Common name | Botanical name | Density | Origin of the timber |
|---|---|---|---|
| Red birch | Bursera simaruba | 22 | Jamaica |
| Binuang | Octomeles sumatrana | 25 | N. Borneo |
| Sitka spruce | Picea sitchensis | 27 | England |
| Black poplar | Populus nigra | 28 | England |
| Haiariballi | Alexa leiopetala | 30 | British Guiana |
| Light red seraya | Shorea leptoclados | 31 | N. Borneo |
| African mahogany | Khaya ivorensis | 32 | Ghana |
| Light red seraya | Shorea waltoni | 33 | N. Borneo |
| Light red seraya | Shorea smithiana | 33 | N. Borneo |
| White seraya | Parashorea malaanonan var. tomentella | 33 | N. Borneo |
| Douglas fir | Pseudotsuga taxifolia | 33 | England |
| African canarium | Canarium schweinfurthii | 33 | Nigeria |
| Mushebeya | Albizia glaberrima | 35 | Uganda |
| African mahogany | Khaya anthotheca | 35 | Ghana |
| White seraya | Parashorea malaanonan | 35 | N. Borneo |
| Nazingu | Nitragyna stipulosa | 35 | Uganda |
| Muchenche | Newtonia buchanani | 35 | Uganda |
| Nkoba | Lovoa brownii | 38 | Uganda |
| Aningeria | Aningeria altissima | 38 | Uganda |
| Crabwood | Carapa guianensis | 39 | British Guiana |
| Niangon | Tarrietia utilis | 39 | Ghana |
| Makore | Mimusops heckelii | 39 | W. Africa |
| Dark red seraya | Shorea pauciflora | 40 | N. Borneo |
| Mugisi | Bosqueia phoberos | 40 | Uganda |
| Poon | Calophyllum tomentosum | 42 | India |
| Baromalli | Catostemma commune | 42 | British Guiana |
| Keruing | Dipterocarpus caudiferus | 43 | N. Borneo |
| Okwen | Brachystegis nigerica | 43 | Nigeria |
| Berlinia | Berlinia spp. | 44 | Nigeria |
| Afromosia | Afrormosia elata | 44 | Ghana |
| White star apple | Chrysophyllum albidum | 44 | Uganda |
| African mahogany | Khaya grandifoliola | 44 | Nigeria |
| Dahoma | Piptadeniastrum africanum | 44 | Uganda |
| African satinwood | Fagara macrophylla | 46 | Uganda |
| Mubura | Parinari excelsa | 46 | Uganda |
| Adwea | Dacryodes klaineana | 48 | Ghana |
| Brown sterculia | Sterculia rhinopetala | 48 | Nigeria |
| Nkobakoba | Baikiaea insignis sub sp. minor | 50 | Uganda |
| Yellow sterculia | Sterculia oblonga | 50 | Nigeria |
| East African olive | Olea hochstetteri | 55 | Sudan |
| Muhimbi | Cynometra alexandri | 56 | Uganda |
| Mora | Mora excelsa | 60 | British Guiana |
| Morabukea | Mora gonggrijpii | 60 | British Guiana |

Fig. 2.—The Platen-oven, a machine for rapidly determining the moisture content of veneer samples.

in the piles of dried veneer. In practice, veneers are usually dried to an average moisture content of below 10 percent, and the mold danger is then not very real because the occasional wet patch which occurs quickly conditions to below the mold level. The second, and probably the more important consideration, is the effect of the presence of wet patches in the veneer on the gluing process. Most plywood is made in hot presses at temperatures which may exceed 100°C. (212°F.) This is the case especially in British plants were the bulk of the production is "Weather and Boil-proof" (5) material made with phenolic adhesives that set at about 115°C. (239°F.). At these temperatures, excess moisture in the veneers can result in the formation of steam pockets during pressing and blisters in the plywood. For this reason, it is essential that the freshly dried veneer is conditioned to a more uniform moisture content before gluing. It should be pointed out, however, that some airflow dryers, mainly of the cross-flow, compartment type, have provision for conditioning the veneer at the end of the drying cycle. Although it is doubtful whether a completely uniform moisture content is attained in the time available, the conditioning section must considerably reduce the moisture content variations.

## Natural Conditioning of Freshly Dried Veneers

It is common practice in most hardwood plywood factories to close-pile the freshly dried veneer until it is required for further processing. During this storage period, which can vary from a few hours to even weeks, the variation in moisture content decreases; an indication of the rate of change is shown by the following tests (6). A 5-foot long, 2½-foot wide, and 2-foot high stack was constructed of freshly dried 0.064-inch beech (*Fagus sylvatica*) veneers and weighted to simulate the conditions in a tall pile. The stack was located in an air-conditioned room where the equilibrium moisture content was 10 percent, and veneers were withdrawn at intervals for immediate moisture content tests. The results of this investigation are given in Figure 4. Two separate tendencies can be recognized. First, there is an equalization of the moisture content within each veneer. This process is fairly rapid in the early stages, independent of the conditions of the surrounding air and need not cause any change in the "average" moisture content of the veneers. Second, the "average" moisture content slowly approaches that in equilibrium with the conditions of the surrounding air. The natural conditioning process is slow, the difference between the "spread maximum" and the "spread minimum" takes 28 days to decrease from 18 percent with an average moisture content of 11 percent to 4 percent with an average of 10 percent. It should be noted, however, that only one day is required for the "spread maximum" to drop from 22 percent to below the mold level, and although beech has a "less than normal" variation, it is obvious that species with a "greater than normal" variation will quickly become safe. It is common practice at the Forest Products Research Laboratory to dry veneers to an "average" moisture con-

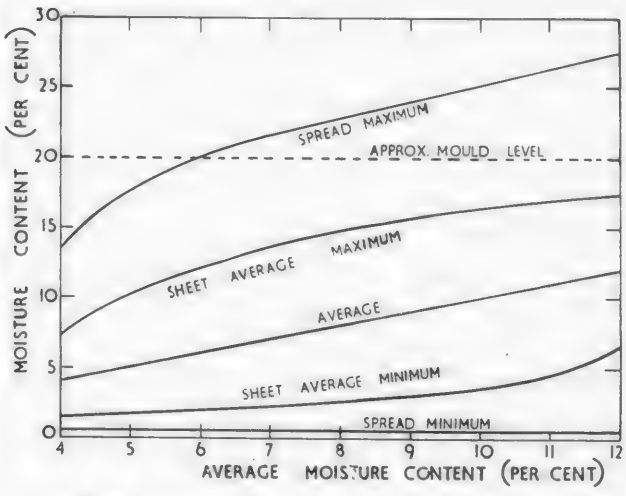


Fig. 3.—An analysis of the variation in moisture content of freshly dried veneers from 48 species. (Limits within which 99 percent of the samples lie.)

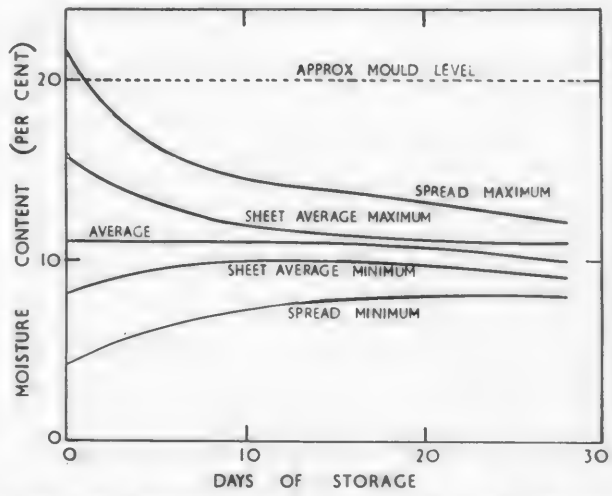


Fig. 4.—The equalization of moisture content in a pile of freshly dried beech veneers.

Table 2.—THE FORCED CONDITIONING OF VENEER*

| Air temperature °C. | Initial moisture content, percent | Veneer thickness, inches: 0.064 — Air speed, ft./min. 80 | 0.064 — Air speed, ft./min. 162 | 0.064 — Air speed, ft./min. 355 | 0.102 — Air speed, ft./min. 80 | 0.102 — Air speed, ft./min. 162 | 0.102 — Air speed, ft./min. 355 |
|---|---|---|---|---|---|---|---|
| 80 | 20 | 26 | 22 | 21 | 50 | 45 | 33 |
| | 0 | 16 | 12 | 14 | 24 | 22 | 19 |
| 100 | 20 | 23 | 17 | 14 | 32 | 28 | 23 |
| | 0 | 11 | 12 | 10 | 19 | 23 | 21 |
| 106 | 20 | 18 | 14 | 13 | 26 | 22 | 19 |
| | 0 | 14 | 14 | 10 | 20 | 18 | 20 |

* Time (minutes) to attain 10 ±1 percent moisture content. The values given in the table are actual observations.

tent of between from 6 to 8 percent; i.e., occasional wet patches of more than 20 percent moisture content occur, and mold growths have not been found during the natural conditioning which follows the drying.

The relationship between moisture content and the occurrence of blisters at any one pressing temperature is difficult to establish because of dependent variables such as the glue brand and type, the amount of glue spread and the closed assembly period, the species, and even the wood grain itself. In practice, the situation is even more complicated, although the full-size sheets remain in a stack between drying and pressing, the veneers, which are under full size, are usually edged and spliced together, a process during which the veneers are freely exposed to the shop conditions and thus can condition more quickly. Nevertheless, if it is considered that the "spread maximum" in the veneer should not exceed 14 percent on entering the glue spreader then, with the permeable beech (*Fagus sylvatica*), 14 days must be allowed for natural conditioning between drying and bonding. It is common practice at the Forest Products Research Laboratory to store the freshly dried veneers for at least 3 weeks before pressing at 115°C. (239°F.) and blistering has not occurred in the ½-inch thick plywood which is normally produced.

## Forced Conditioning of Freshly Dried Veneers

Due to the slowness of the natural conditioning method, small scale tests (7) were initiated to determine whether the rate of moisture change could be increased. Samples of gaboon (*Aucoumea klaineana*) veneer with thicknesses of 0.064 inch and 0.102 inch were individually exposed to a controlled air stream. The temperature and speed of the circulating air was varied in steps between 60°C. (140°F.) and 106°C. (223°F) and 80 feet per minute and 355 feet per minute respectively. The relative humidity was controlled to give, in each case, an equilibrium moisture content of 10 percent in the wood. Provision was made for quickly withdrawing the 36-inch by 6-inch samples, after a pre-selected time, so that the moisture content of the center portion could be determined.

Table 2 gives the time taken for the two thicknesses of veneer to condition of 10 percent moisture content. The rate of moisture change generally increases as the temperature and speed of the circulating air are raised, and under the most favorable conditions times of approximately 13 minutes are required for 0.064-inch veneer, initially at 0 and 20 percent moisture content, to approach within 1 percent of the equilibrium value. These small scale tests show that the natural conditioning of freshly dried veneer can be hastened considerably by employing the forced method.

## Conclusions

When veneers are dried in mechanical dryers they usually emerge with a wide variation in moisture content both within and between the individual sheets. Although the species of veneer has some effect on the variation, the controlling factor is the average moisture content to which the veneers are dried. The variation decreases as the average moisture content is lowered but, even with an average of 6 percent, wet patches of more than 20 percent moisture content occur.

If freshly dried veneers that contain wet patches are glued in presses heated to over 100°C. (212°F.), steam pockets may form and cause blisters in the plywood. It is essential, therefore, that freshly dried veneers be conditioned before gluing. This can be achieved by storing the veneers in piles, when the moisture content variation slowly decreases, but periods of weeks rather than days are necessary for the attainment of a uniform moisture content. The alternative to natural conditioning is the forced conditioning of the individual veneers in a suitably designed chamber which can be arranged at the outfeed end of the dryer. Small scale tests indicate that a uniform moisture content can be obtained with 0.064-inch beech (*Fagus sylvatica*) veneers in approximately 13 minutes.

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# The Lumber Industry:

# NEW LEADERSHIP[1]

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**The time has come for the lumber industry to assume a new role of leadership. The time is NOW. Here is the challenge to the lumber industry in the sixties. No longer can wood afford to decline on the market; it must remain the inherent component of housing. Continual success of the industry is dependent upon the retention and expansion of this market.**

IN A RECENT EVALUATION OF THE building industry outlook for the 1960's, the F. W. Dodge Corporation indicated that new construction during this decade will provide a market for more than $650 billion in goods and services. The estimate, based on 1959 dollars, indicates that this is by far the largest market ever obtained by any fabricating industry. It was further estimated that by 1969 new residential construction will amount to $31.1 billion annually. This will mean that roughly 40 percent of the new construction market for the 1960's will be provided by residential housing.

These figures indicate that the housing market for the 1960's represents the largest single outlet for lumber and wood products. Because frame construction has dominated the residential housing market for many years, the lumber industry has enjoyed a substantial portion of this billion-dollar industry. The degree that the lumber industry is dependent upon housing to sustain the demand for wood is shown when we compare housing starts and lumber production since 1947. The peaks in lumber production are closely related to the three significant housing booms which developed during this period.

It is also interesting to note that each successive peak in lumber production has been somewhat lower than the previous one. Although this decline in lumber production may reflect losses of wood markets other than housing, it must be admitted that the consumption of lumber per housing unit has declined.

In the past 20 years, architectural changes in house design and the inroads of competing material have substantially reduced the lumber industry's proportionate share of the housing market. This trend must be vigorously altered by the lumber industry if it expects to retain a dominate postion in the housing field. It seems clear that the continued success of the lumber industry is dependent upon its ability to retain and expand its present proportion of housing business and to recover markets which have been lost in the past 10 years.

The housing market for the 1960's will be totally different from that which has existed during the past 15 or 20 years. There are indications that the position of residential construction in the general business cycle has shifted. During the recent post-war period, housing tended to run counter to the normal business cycle, often being stimulated by lower money rates associated with a recession. Now, however, there are indications that it is responding in the same manner as the general business cycle.

One reason for this shift is that the driving force of a backlog of demand for housing created by people living in crowded conditions has diminished; the demand now is coming largely from new-family formation.

Population statistics revealed by the 1960 census provide an indication of the nature of the demand for housing in the next decade. According to the census figures, the greatest percentage gain during the 1960's will be in the age group of 20 to 24. Another significant increase will be in the

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number of people over 65, which will show a gain of 25 percent for the next 10 years. On the other hand, the home buyer age group, that is, men between the ages of 30 and 40, will show a decrease of almost 1 million. If this most important group of home buyers is expected to decrease by 1 million, it is clear that the 1960's will provide a different home sales market than that of the booming 1950's.

In order to accomplish the objective of providing more house for the money and also providing houses which will appeal to low-income groups such as young newly married adults and citizens over 65, the homebuilder will be more inclined to experiment with a profusion of new materials and techniques to develop practical, labor-saving solutions. Herein lies a major challenge to the lumber industry. Wood must be one of these materials.

More important, the wood industry must establish itself as the fundamental source for new ideas and construction techniques which will assist the builder to cut costs. This position of leadership must not pass by default to competitive industries.

Another significant aspect of the housing market which must not be ignored by the lumber industry is the degree to which the manufactured home, and its principle of component construction, has penetrated the housing market. Many believe that component construction provides the basic solution to the problems of low-cost construction facing all homebuilders today. The growth of the prefabricated housing industry over the past 10 years shows a definitely uniform percentage increase. At the present rate, within 10 years manufactured homes will enjoy almost 25 percent of the single-family housing market.

Because component construction and labor-saving erection are fundamental to manufactured homes, these companies are interested in products and materials which are easier and more economical to use. Furthermore, they are prepared to enter into exclusive agreements with major material producers who can satisfy these requirements. The lumber and wood products industry cannot afford to let this rapidly growing market slip into the hands of competition.

There should be no doubt, therefore, that action is required. The action our industry's leaders have proposed is a coordinated industry-wide program of technical investigations directed primarily to serve the homebuilding industry. This bold move is designed to assure the lumber industry a position of authority in the housing market.

### Promotion of Wood

The National Wood Promotion Program (NWPP) has demonstrated that it can create a consumer preference for wood. Because of the appealing qualities of wood, we can accomplish this at a cost considerably below that required by competitive materials. In most cases, the competition must first create a desire for their product which is new and unfamiliar.

However, if we are to take advantage of the market opportunities being created by the NWPP, we must be beyond such platitudes as "wood is good," "there is nothing in the world like wood." New engineering data, new facts, new construction ideas must be developed that will make wood easier and more economical to use.

Today our industry has a small field force which, in quality, is second to none in the nation. We must continue to give these men the new information they will need to do an effective selling job. Remarkable as the properties of wood are, we cannot expect to continue to stand on them alone. The architect, builder, contractor, and home manufacturer are practical customers. We must give them workable ideas—ideas which sell themselves and sell wood because they make it easier to use. Such ideas are not born from imaginative daydreaming but from sound and realistic engineering studies developed by a coordinated team of engineers, architects, and wood technologists.

The rather disorganized pattern of technical data now emanating from a wide variety of institutional research programs presents a confusing picture to the designer, builder, and home manufacturer. It is not in a form which is readily understandable or useable on the job.

This is not to detract from the contributions of government or university research activities. In fact, development of sound engineering and technology data cannot be accomplished without this fundamental information. However, the direction, coordination, and application of such technical information in a form designed to make wood easier and more economical to use should originate within the lumber industry.

### Industry Technical Studies Program

To define the scope of activity of a coordinated technical studies program in the field of engineering and construction technology, it should be stated that basic or fundamental studies would be the responsibility of governmental and institutional laboratories. Specific wood product development, likewise, would be considered clearly a function of individual lumber manufacturers.

Between the two areas of "fundamental investigations" and "wood product development" lies the important intermediate category of "engineering and construction technology" with which we are concerned. This activity may be further divided into two major areas:

1. Presentation of current information on wood in the form of attractive design and construction literature and films for architects, builders, and building officials. This area is, of course, of immediate importance to our industry and currently is being handled effectively through the technical activities of the NWPP.
2. The second area consists of developing new engineering data, new design concepts, and construction ideas for wood use. It is in this important area that relatively little is being done by our industry on a coordinated basis in comparison with the efforts of our competitors. This would be the responsibility of carefully selected teams of engineers, architects, and wood technologists who would specialize in improving the use and acceptability of wood for light-frame constructions.

### Present Technical Studies Program of NLMA

A brief description of the technical data currently being developed within the National Wood Promotion Program will illustrate how we obtain existing design and construction information for wood into the hands of builders, architects, and others in the construction industry. It will also reveal some of the important areas wherein new information should be developed if we are to continue to retain our residential and light-frame construction markets.

**Heating and Air Conditioning Studies:** Presently we are developing information on the comparative heating and air-conditioning costs of wood-frame construction in contrast to solid masonry. The data obtained indicate that substantial savings are possible with wood-frame construction and will be used in the preparation of technical literature on this subject for designers and builders. With an eye to the future, however, our industry must

improve and promote the superior insulation characteristics of wood frame construction more effectively.

**Fire Testing:** Our comparative fire tests conducted at the Southwest Research Institute have produced a dramatic color movie and technical report which illustrates the superiority of exposed heavy-timber construction over unprotected light-steel framing when subjected to fire. This test series is continuing with tests of glu-lam versus rolled steel beams and of fire-retardant-treated wood scheduled. We must develop ways to improve the natural fire durability of wood through coatings, impregnation, and structural combinations with other materials.

**Multiple-Member Assemblies:** When small wood structural members such as studs, joists, and rafters are used in a repetitive manner in wall, floor, and roof assemblies so that loads are distributed to adjoining members, there is good evidence to indicate that present design criteria may not result in the most efficient use of lumber.

A testing program which is presently being planned should provide strength data which will result in more economical wood frame construction. With an eye to the future, however, we must conduct full-scale physical tests of wood floor, wall and roof systems to determine accurately the stresses required in house construction.

**Grade Simplification and Standardization:** Our industry is currently engaged in a program of grade simplification and standardization designed to make wood easier to specify and simpler and more economical to use. With an eye to the future, we must conduct a careful analysis of building requirements to assist in the tailoring if lumber grades to major construction applications.

**New Floor Systems:** Our first approach to the area of new design information on wood is the current study to develop new wood floor systems which will compete effectively with concrete slab construction.

This investigation is of particular interest because it has the potential of permitting lumber to regain a lost market and may lead to the development of a much-needed, all-wood foundation. This is the type of technical study which should be undertaken as a part of a coordinated industry engineering and technology program.

**Component Construction System for Housing:** A second activity presently underway in our technical promotion program which is concerned with the development of new data is a study to establish a standardized lumber-industry component construction system.

The system features the use of standard lumber sizes and will be suitable for the small home builder, the volume home builder, and the home manufacturer. This project anticipates the trend toward component construction and is designed to preserve this market for wood.

**Wood Design Data:** Easy-to-use design data for framing lumber is needed to provide the home builder and designed with information enabling him to utilize the most economical sizes and grades of material without difficulty and confusion. One continuing series of technical publications is called the "Wood Construction Data" series.

These publications are being widely distributed to builders, architects, contractors, and have probably stimulated greater interest within the design and construction industry than any other technical promotion activity.

The publications are based upon existing information as well as data being obtained from our heating and air-conditioning and fire-test studies. They fill a long vacant need for easy-to-read, authoritative data. However, to be most effective in the future, the series should contain new information obtained from new technical studies aimed at improving the use and performance of wood.

**Durable Exterior Finishes for Wood:** A study is planned to provide for the development of high performance paints and other finishes for exterior wood surfaces. Details of the program for this study were developed at a joint lumber and paint industry workshop conference held recently.

From this brief description, I have attempted to illustrate what our present program is accomplishing. We can now begin to evaluate the adequacy of current activities in terms of the type of information we shall need in the next 10-year period. I believe that we can agree that our present program is bringing us only up to the level of our competition. We shall require new ideas, new systems, new construction methods, if we are to lead in the housing field in the years ahead.

## Future Projectives

The lumber industry's progressive plan for the future is based on the recommendations of a newly constituted Special Committee on Technical Studies (composed of a balanced proportion of lumber industry technical directors and principals). On this basis, the Technical Services Division of NLMA will direct a comprehensive program of technical investigations designed to make wood easier and more economical to use.

**Expanded Efforts:** In addition, the leaders of our industry have recently recommended that this effort be expanded to provide a team of competent architects, engineers, and wood technologists working to produce the cost-saving techniques that will be needed to attract the home builder in the 1960's.

To provide the kind of leadership in home construction technology which the architect, engineer, and builder will require, the expanded effort will have to consider at least two important areas:

*Adhesive bonding and mechanical fastening of wood members in all types of structural and non-structural assemblies:* This area would include such problems as a more complete exploitation of the structural end-joint, the development of fastenings for installation of factory-finished siding (currently being studied by the Timber Engineering Company) and simplification of design data for common fastenings such as nails, screws, and bolts. Present information is far too complicated for the average user to understand and use.

*Continuing Development of More Precisely Engineered Lumber and Wood Structural Assemblies to Provide for a More Economical Use of Materials:* This area would include the introduction of new structural systems, new construction techniques, and new methods of fabrication of wood assemblies. Such activity will stimulate the homebuilding industry to consider the lumber industry as the basic source for new design and fabrication techniques for house construction.

As this new and dynamic role for the lumber industry develops, the scope of activities of the engineering and construction technology effort will expand into many other areas where opportunities are found to more effectively promote the use of wood in housing.

The time for the lumber industry to assume this role is *now*. If aggressively maintained, this comprehensive plan will establish wood and wood products as the preferred material for residential construction.

The Home Building Industry has often urged us to take this step, and we propose to accept the challenge. We in the lumber industry believe that this plan will assure the future of the entire wood industry. We are proud of this new venture in wood promotion, and we hope that the present discussion will stimulate both interest and support.

# Weight As A Measure of Volume

## FOR SOUTHERN YELLOW PINE TIMBER[1]

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**In the South, pulpwood is bought and sold by weight. The system works so well, many industries are applying it to pine saw timber. Data presented here, however, show that log scaling by weight is less accurate than the present method based on diameter and merchantable length. Cruising standing timber by weight appears even more questionable.**

UNTIL A FEW YEARS AGO, most pulpwood was bought by the cord and saw logs were purchased on a log scale basis. Now, pulpwood rather generally is being bought by weight and the trend towards buying saw logs by weight is spreading. Some thought has also been given to estimating standing trees and even boundaries of timber by weight. To supplement information on weight transactions, the Southeastern Forest Experiment Station of the U. S. Forest Service, the Georgia Forest Research Council, and the Georgia Forestry Commission in 1960 cooperated in a study of the weight-volume ratio of longleaf, slash, loblolly, and shortleaf pine (5).

### Previous Work

Before the Georgia study was undertaken, a review of former work showed that several investigations had been made of the weight-volume relationship of pine pulpwood and pine saw logs in the South. One of the earliest studies of this kind was by Schumacher (7) in 1946 and involved data from 127 truckloads of saw logs and pulpwood logs from 13 different tracts in the coastal plain of North Carolina and Virginia. In this study, volume scale per 100 pounds of weight was 8.83 board feet for pulpwood logs and 10.83 board feet for saw logs based on the International ¼-inch rule. These values were subject to a standard error of 10 to 12 percent if applied to the weight data for a single tract and 2.5 to 3 percent if applied to the weight data of a group of timber tracts. From this study, Schumacher concluded that, "Volume of logs may be calculated from green weight by the application of the appropriate volume-weight ratio."

Guttenberg, Fassnacht, and Siegel (2) developed a factor for predicting green lumber tally from logs of various weights:

$$\text{Board feet} = \frac{\text{weight}}{9.88} + \frac{(\text{weight})^2}{254{,}362} - 10.96.$$

Based on data from a study of 203 pine saw logs from southern Arkansas and northern Louisiana, the authors state. "Scaling by weight promises equal accuracy and greater day-to-day consistency in predicting lumber yields from southern pine saw logs than scaling by traditional log rule methods."

Lange (3) of the Army Engineers was favorably impressed by results obtained from sales of timber by weight. He says, "We conclude from the investigations that the weighing of forest products may well prove to be the system that we are looking for."

Table 1 was developed by McGee (4) for planted slash pine for a top diameter of 4 inches. He feels that most pulpwood will eventually be bought and sold by weight rather than cubic volume.

Taras (8) concludes that, "Since wood is a heterogeneous material, it is not possible to develop a single factor that will serve all existing variables and can be used for wood in general." However, Taras did develop weights for four southern yellow pine species based on average values for specific gravity and moisture content and assuming a standard cord to contain an average of 72 cubic feet of solid wood (Table 2).

Wahlenberg (9) compiled a table showing the weight of loblolly pine trees based on volumes by MacKinney and Chaiken, and volume-weight ratios by Barron and Osborn (Table 3).

### The Georgia Study

The cooperative study in Georgia evaluated moisture content, specific gravity, percent of heartwood, and proportion of summer-wood to springwood for the purpose of establishing weight-volume relationships.

According to "The Wood Handbook," the average specific gravity generally ranges from a low of 0.46 for shortleaf to 0.47 for loblolly, 0.54 for longleaf, and a high of 0.56 for slash (1). In this study, specific gravity varied from a low of 0.47 for loblolly to 0.49 for longleaf and a high of 0.51 for slash (Table 4). Spe-

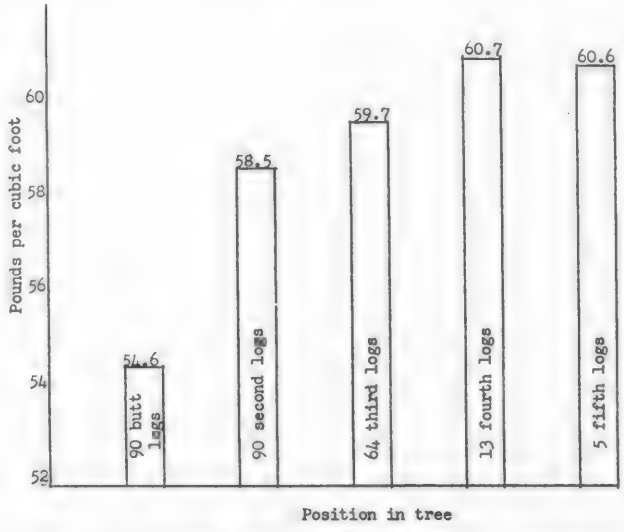


Figure 1.—Weight per cubic foot of green southern yellow pine saw logs by position in tree.

[1] Presented at FPRS 15th Annual Meeting, Session XVI, Timber Production, Louisville, Ky., June 22, 1961.

Table 1.—MERCHANTABLE WEIGHT, IN POUNDS, INCLUDING BARK, FOR SLASH PINE PLANTED ON OLD FIELDS IN THE CAROLINA SANDHILLS

| D. b. h. (Inches) | Total tree height in feet— | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 |
| 5 | .. | 32 | 45 | 64 | 82 | 100 | 119 | 137 | 155 | | | |
| 6 | 42 | 67 | 94 | 120 | 146 | 173 | 199 | 226 | 252 | 279 | | |
| 7 | | 115 | 151 | 187 | 223 | 259 | 295 | 331 | 367 | 403 | 439 | |
| 8 | | | 217 | 264 | 311 | 358 | 405 | 452 | 499 | 546 | 593 | 640 |
| 9 | | | | 351 | 411 | 470 | 530 | 589 | 649 | 708 | 768 | 827 |
| 10 | | | | | 522 | 596 | 669 | 743 | 816 | 890 | 963 | 1037 |
| 11 | | | | | 646 | 734 | 824 | 913 | 1001 | 1090 | 1179 | 1268 |
| 12 | | | | | 781 | 887 | 992 | 1098 | 1204 | 1310 | 1416 | 1521 |

Table 2.—WEIGHTS FOR THE VARIOUS PINE SPECIES IN THE SOUTHEAST

| Species | Specific Gravity | Moisture Content (Percent) | Density (Lbs. Cu. Ft.) | Vol. Per Cord (Cu. Ft.) | Calculated Wt. without Bark (Lbs.) | Estimated Wt. of Bark (Lbs.) | Calculated Wt. with Bark (Lbs.) |
|---|---|---|---|---|---|---|---|
| Loblolly pine | 0.46 | 110 | 63.3 | 72 | 4557 | 700 | 5257 |
| Longleaf pine | 0.53 | 105 | 67.8 | 72 | 4881 | 650 | 5331 |
| Shortleaf pine | 0.44 | 120 | 60.4 | 72 | 4349 | 500 | 4849 |
| Slash pine | 0.52 | 120 | 71.4 | 72 | 5140 | 500 | 5640 |

cific gravity of shortleaf was not measured.

In the Georgia study, moisture content varied significantly by position in the tree. Top logs were consistently wetter than butt logs (Table 4), which differs somewhat from Peck's findings (6). Apparently, moisture content influenced weight to a greater extent than did specific gravity, since top logs weighed more per cubic foot than butt logs (Fig. 1), although specific gravity decreased from butt to top (Table 4).

The percent of heartwood affects the weight of pine logs and timber because the moisture content of southern yellow pine heartwood is usually about 30 percent as compared with 110 to 125 percent for the sapwood (1). Even though second growth pine does not usually contain much heartwood, even a small amount may affect the weight of saw logs by position in tree. Table 5 shows the proportion of heartwood of some sample logs in the Georgia study.

An analysis of sample logs showed no significant difference in the proportion of summerwood to springwood by position in tree.

One of the most important findings in this study was the wide difference in weight of logs needed to make a thousand board feet of lumber. Small logs produce a higher percentage of "non-lumber" material than large logs, and thus small logs yield less lumber per unit of weight than large logs (Table 6).

How accurately, then, can we predict the yield of pulpwood, lumber, or other products from the weight of bolts, logs, or trees?

Because weight tends to combine the effect of volume, specific gravity, and moisture content, it can be used to predict the cubic volume of pulpwood for a large number of units. However, weight alone is not a reliable measure of cubic volume for single bolts or trees because the weight-volume ratio of pine varies by species, between trees in the same tract, and within the tree itself.

Here, it is important to recognize that pulp companies are less interested in wood volume *per se* than in pulp yield, which is measured in terms of weight. Therefore, it appears that those industries measuring raw material in terms of pounds of fiber have biologically sound reasons for using weight rather than volume, and, conversely, weight-cubic volume ratios become relatively unimportant to them.

The situation in the case of lumber is quite different. The prediction of board foot volume differs from the prediction of cubic foot volume because lumber yield is affected by physical dimensions—diameter, length, and form—and not by specific gravity and moisture content, whereas weight *is* affected by specific gravity and moisture content. Lumber yield predicted from weight, in the case of individual units or small numbers of logs, is therefore not reliable unless the prediction is modified by diameter and length. It has, however, been shown that weight alone can be used to predict the volume of a large number of logs within acceptable limits of accuracy (2), (3), (5), (7). This is because averages vary much less in large than in small samples.

Since we can predict the yield of lumber from logs using only diameter and length, why are we interested in using weight to predict lumber yield, particularly if the weight of a small number of logs has to be modified by diameter and length? Weight scaling of saw logs seems desirable for several reasons. It permits faster truck turnaround time, eliminates errors that frequently occur in conventional log scaling, and encourages delivery of fresh logs free from stain and decay. The most serious disadvantage to weight scaling at present is its failure to establish a price differential for logs of different size and grade.

## Prediction of Whole Tree Weight

Analysis of a limited amount of data from the Georgia study shows that even larger biologic variations may occur in trees than in logs. This is so because the range of specific gravity and moisture content, both of which are affected by the percent of heartwood and juvenile wood, may differ less in logs than in whole trees, which vary in size from stump to top. Thus, for trees, it is necessary to base volume predictions by weight on even larger samples to assure any degree of accuracy of the average. Again, in the case of scaling tree length logs by weight, which is only an extension of weight scaling standard length logs, the error will be larger in absolute value (though perhaps smaller in percent) because of this wider range in specific gravity and moisture content.

To predict the weight of trees on a basis of diameter and merchantable length, 111 trees were reconstructed from a total of 250 sample logs used in the Georgia weight-volume ratio

Table 3.—WEIGHT OF FRESHLY CUT LOBLOLLY PINE PULPWOOD (GREEN WOOD WITH BARK) BY HEIGHT AND DIAMETER OF TREES

| Diameter breast high outside bark (inches) | Total height of trees (feet) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | Pounds per tree | | | | | | | |
| 6 | 88 | 139 | 195 | 242 | 280 | 329 | | |
| 7 | 141 | 212 | 275 | 338 | 399 | 459 | 520 | |
| 8 | 206 | 289 | 375 | 457 | 536 | 612 | 691 | |
| 9 | 271 | 377 | 484 | 588 | 690 | 791 | 886 | |
| 10 | 342 | 477 | 608 | 737 | 863 | 985 | 1,103 | |
| 11 | | 588 | 748 | 905 | 1,057 | 1,201 | 1,347 | 1,485 |
| 12 | | 720 | 902 | 1,087 | 1,267 | 1,441 | 1,613 | 1,781 |
| 13 | | 847 | 1,071 | 1,286 | 1,498 | 1,706 | 1,907 | 2,096 |
| 14 | | 994 | 1,251 | 1,502 | 1,751 | 1,990 | 2,219 | 2,440 |
| 15 | | 1,153 | 1,448 | 1,740 | 2,023 | 2,292 | 2,591 | 2,849 |
| 16 | | 1,320 | 1,664 | 1,997 | 2,312 | 2,655 | 2,958 | 3,310 |
| 17 | | 1,503 | 1,893 | 2,264 | 2,629 | 3,009 | 3,409 | 3,750 |
| 18 | | | 2,136 | 2,550 | 2,990 | 3,449 | 3,842 | 4,220 |
| 19 | | | 2,391 | 2,892 | 3,361 | 3,858 | 4,296 | 4,720 |
| 20 | | | 2,662 | 3,222 | 3,794 | 4,297 | 4,787 | 5,259 |
| 21 | | | | 3,537 | 4,237 | 4,732 | 5,247 | 5,795 |

Table 4.—VARIATION IN SPECIFIC GRAVITY AND MOISTURE CONTENT OF SAMPLE TREES

| Position | Loblolly | | Longleaf | | Slash | |
|---|---|---|---|---|---|---|
| | Specific gravity | Moisture content (Percent) | Specific gravity | Moisture content (Percent) | Specific gravity | Moisture content (Percent) |
| Butt log | 0.49 | 89.1 | 0.49 | 90.3 | 0.53 | 80.9 |
| 2nd log | 0.46 | 97.1 | 0.48 | 96.1 | 0.49 | 92.9 |
| 3rd log | 0.43 | 104.5 | 0.48 | 88.9 | 0.48 | 94.3 |
| Tree | 0.47 | 94.5 | 0.49 | 92.0 | 0.51 | 86.6 |

Table 5.—PROPORTION OF HEARTWOOD BY SPECIES

| Position | Shortleaf | Loblolly | Longleaf | Slash |
|---|---|---|---|---|
| | Percent | | | |
| Butt log | 17.3 | 7.8 | 10.4 | 11.5 |
| 2nd log | 15.8 | 4.4 | 5.4 | 7.4 |
| 3rd log | 12.2 | 1.8 | .9 | 4.0 |
| 4th log | 9.0 | .4 | ---- | 2.1 |
| 5th log | .4 | --- | ---- | ---- |
| Tree | 15.1 | 5.2 | 7.7 | 9.0 |

study. These sample trees and logs contained a total of 11,461 board feet, and were taken from 7 different locations in Georgia (Table 7).

A multiple regression analysis was run to develop prediction equations for each of the 4 species sampled. Of the variables examined, the only one that proved significant and that really affected tree weight was $D^2L$ (where D = diameter and L = merchantable length), except for shortleaf pine, in which $D^2L$ plus $D^2$ proved more significant than $D^2L$ alone. These equations, using only $D^2L$, where Y = Weight, are:

longleaf ----- $Y = .1701005\ (D^2L) + 297.217937$
loblolly ----- $Y = .1814272\ (D^2L) + 40.587823$
slash ---------- $Y = .1662041\ (D^2L) + 272.670912$
shortleaf ----- $Y = .1831807\ (D^2L) - 170.591947$

Using these equations, a graph was drawn for each of the four species to prefer tree weight based solely on $D^2L$.

The mean squares for shortleaf were significantly greater than for the other species. The reason for this is not clearly apparent. The prediction equation developed for shortleaf using both $D^2L$ and $D^2$ is: $Y = .1312960\ (D^2L) + 3.876683\ (D^2) - 111.387474$.

The standard errors for the weights of individual trees computed from the prediction equations vary by species as follows: longleaf pine 126, slash pine 184, loblolly pine 175, shortleaf pine 297. These standard errors are obviously so large that these data cannot be used for prediction purposes. However, with sufficient data (probably a hundred or more trees for each species with satisfactory distribution of diameters) such a regression could be developed so that the slope of the line would be very accurate. Having the correct slope, however, would not reduce the variation of single trees above and below this line.

The next logical step would be to correlate lumber yield with tree weight, tree diameter, and tree length and develop equations for predicting board foot volume in cases of given tree weight and size. The sample in the Georgia study is not adequate to do this because of very few observations in some size classes.

Even without these equations, it appears that we are limited in developing any system that can be used to convert weight accurately to volume of single trees, unless we measure and use the variables of specific gravity and moisture content. Hence, on a basis of limited investigations, cruising timber by weight appears to have serious limitations. If weight scaling standing timber is practiced, it must be justified for one of two reasons: 1) it is cheaper, or 2) it has greater precision than conventional methods.

There are no figures documenting the relative cost of weight scaling, and limited data indicate that errors for standing trees are greater for weight scaling than for stick scaling. If further study proves weight scaling more economical, then we need to know how far we can go in sacrificing precision for economy.

## Summary

Although many industries are going rapidly to a system of weight measurement, it is not generally appreciated that the effects of specific gravity and moisture content cause considerable variation in individual weight measurements of pulpwood, saw logs, and whole trees.

Buying by weight works well with pulpwood because weight tends to combine the effect of volume, specific gravity, and moisture content. Moreover, the weight per cubic foot is not significantly influenced by diameter. In addition, pulp companies are more interested in pulp yield, which is measured by weight, than in actual volume. On the other hand, weight transactions appear less accurate for individual saw logs because of the wide difference in lumber yield for the same weight of logs of different size. Scaling standing trees by weight promises even less accuracy than scaling logs by weight because of a wider range in specific gravity and moisture content. Hence, it is questionable that the prediction of volume of standing trees from weight would involve fewer calculations or be more accurate than the present method of predicting volume from diameter and merchantable length.

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Table 6.—GREEN WEIGHT OF PINE SAW LOGS NEEDED TO PRODUCE 1 M BOARD FEET OF LUMBER (curved)

| Diameter (Inches) | Green weight of logs | | |
|---|---|---|---|
| | Loblolly and shortleaf | Longleaf | Slash |
| | Pounds | | |
| 5 | 19,400 | 20,000 | 23,600 |
| 6 | 14,100 | 16,300 | 19,000 |
| 7 | 12,900 | 14,500 | 16,800 |
| 8 | 11,900 | 13,500 | 15,200 |
| 9 | 11,300 | 12,800 | 14,200 |
| 10 | 10,900 | 12,200 | 13,400 |
| 11 | 10,500 | 11,800 | 12,800 |
| 12 | 10,200 | 11,400 | 12,400 |
| 13 | 9,900 | 11,200 | 11,900 |
| 14 | 9,800 | 11,000 | 11,600 |
| 15 | 9,600 | 10,900 | 11,300 |
| 16 | 9,400 | 10,800 | 11,000 |
| Weighted average | 10,759 | 13,087 | 14,191 |

Table 7.—TREES AND LOGS SAMPLED

| Location | Species sampled | Trees (Number) | Logs (Number) | Volume (Board feet) |
|---|---|---|---|---|
| Valdosta | Slash | 14 | 35 | 1,350 |
| Cordele | Slash | 12 | 36 | 1,509 |
| Tifton | Slash | 29 | 10 | 876 |
| Total | | 55 | 81 | 3,735 |
| Valdosta | Longleaf | 11 | 29 | 827 |
| Cordele | Longleaf | 4 | 11 | 604 |
| Total | | 15 | 40 | 1,431 |
| Trenton | Shortleaf | 12 | 34 | 1,182 |
| Clayton | Shortleaf | 10 | 42 | 2,079 |
| Total | | 22 | 76 | 3,261 |
| Cochran | Loblolly | 5 | 14 | 531 |
| Gray | Loblolly | 14 | 39 | 2,503 |
| Total | | 19 | 53 | 3,034 |
| | All species | 111 | 250 | 11,461 |

*Chemical Conversion of Wood Residues, Part IV*

# Economics of the Production of Furfural from Xylose Solutions[1]

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**Large quantities of aqueous xylose solutions are available as by-products from various wood-processing industries. Production costs, based on previously reported kinetic-yield data, are estimated for various plant designs. Results indicate that many crude xylose solutions can be profitably processed to furfural.**

ONE HUNDRED AND THIRTY MILLION POUNDS of furfural can be supplied each year to the United States market by two producers. Three plants operated within the continental United States, with an annual capacity of approximately 100 million pounds, process various agricultural residues, principally corncobs. A plant located in the Dominican Republic uses sugarcane bagasse to produce about 35 million pounds of furfural a year. These plants all use the same type of batch process (10, 13).[3] The solid raw material is ground and charged into spherical rotary digesters, where it is impregnated with a small amount of dilute sulfuric acid and digested for about 2 hours at a steam pressure of 100 pounds per square inch. Vapors are withdrawn from the digester and fresh steam is put into it continuously; thus, the furfural is removed from the reaction zone as it is produced and losses reduced. Recovery of the furfural is by rectification.

Despite the chemical versatility and low price of furfural, the bulk of it is utilized in relatively few applications. More than half is used in the production of nylon as raw material to make hexamethylenediamine. The remainder is used as an extractive solvent and for the production of various furan chemicals and resins.

Because of the multiplicity of products that can be derived from the furans, especially the difunctional aliphatic and olefinic types, and because furfural is the most economical source of furans, it undoubtedly has great potential value as a chemical intermediate. The recent interest in lysine (1), which might be produced from furfural, represents a potential market of millions of pounds annually. Another promising large-scale use has been suggested (4) in the refining of rare earths and other metals. It can be visualized that a large domestic supply, in addition to that economically attainable from agricultural waste, will be needed in the future.

Production of furfural might be economically expanded with agricultural wastes similar to those now used, from various xylose-containing solutions that are byproduct streams from some industries using hardwoods, or from hardwoods directly. The work reported here was done as part of a program intended to establish wood as a chemical raw material. The aims of this program have been previously described (7, 8). Throughout the discussion that follows, it is assumed that the aqueous xylose solution would be derived by the prehydrolysis of hardwood with dilute acidic solution, the purpose of this hydrolysis being to separate the xylose-containing hemicellulose from the resistant cellulose and lignin. The resulting solution would contain many constituents. A typical approximate analysis of a wood prehydrolyzate solution from hardwoods is:

| Components | Concentration, percent |
|---|---|
| Acetic acid | 1.5 |
| Methanol | .2 |
| Xylose | 6.0 |
| Glucose | 5.0 |
| Other organics | 1.0 |
| Sulfuric acid | .7 |
| Ash | .5 |
| Water | 85.1 |
| | 100.0 |

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[1] This is the fourth in a series of reports on chemical conversion of wood residues, Parts I, II, and III appeared in Sept. 1958, May 1959, and Feb. 1960, respectively. This is a contributed paper approved for publication May 1961.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to Literature Cited at the end at this report.

This study presents an economic evaluation of the possibility of obtaining furfural and acetic acid from such a solution. The information presented is applicable to other xylose-bearing solutions. In some instances—for example, when evaluating sulfite pulp liquors—additional information may be needed on such matters as the effect of extraneous materials on reaction rates and yields.

In contrast to the batch type of process now being used commercially for furfural production, the process evaluated in this paper is continuous. High throughput and low reaction equipment costs characterize the proposed method. Because of the high reaction temperature employed, heat recovery is of prime importance. By interchange of heat, however, the total process-steam requirements can be reduced to the range of 13 to 16 pounds per pound of furfural. Fouling, another important problem in this process, can probably be held to tolerable limits by proper staging of temperatures and careful choice of heat transfer methods.

### Rate-Yield Data

The kinetics of the sulfuric acid catalyzed conversion of pure xylose to furfural has been intensely studied by Root (15). Using batch reactors and isothermal reaction conditions, information was obtained on the yield of furfural as a function of initial xylose concentration, catalyst concentration, reaction temperature, and time. The variation with time of the furfural concentration in a batch reactor yields a typical growth-and-decay curve reaching a maximum furfural concentration in the vicinity of two to three half-lives. Figure 1 presents these maximums yields of furfural from pure xylose solutions as a function of initial xylose concentration and reaction temperature when a sulfuric acid catalyst concentration in excess of 0.1 N is used. The use of acid concentrations lower than 0.1 N has an adverse effect on yield. This adverse effect increases with increasing temperature. Further details of this relation are given in Root's (15) thesis, which also includes information on the effect of the presence of various materials on the yield. Materials added to the system under study included acetic acid, glucose, and sodium chloride. The important effect of dilution and temperature is illustrated in Figure 1. Furfural yields increase with increasing temperature and decrease with increasing xylose concentration.

The scope of Root's work was very broad. The entire range of variables shown in Figure 1 was studied at various catalyst levels. Experimental results were correlated by an empirical analytical expression derived from a plausible reaction mechanism. This correlation, although derived from isothermal data, was tested and found suitable for predicting yields under non-isothermal conditions. Thus, it was possible to program computations for an electronic computer to make economic evaluations of various plant designs and operating conditions.

To check the validity of applying Root's data to a commercial solution, a concentrated hydrolyzate from a hardboard plant was studied. The experimental technique was identical with that used by Root, but the scope was restricted to a narrow range of commercial interest. Results of this study are shown in Figures 2 and 3.

### *What This Research Means*

Profitable use of the pentose fraction, although it is only a small part of the total wood, can play an important role in the overall picture of using wood economically as a chemical raw material. Such a situation can only occur, however, through the careful evaluation of processing schemes on the basis of fundamental scientific and engineering principles. In two previous articles of this series on the chemical utilization of wood residues, attention was paid to the separation of hardwood hemicelluloses and the bench-scale kinetics of the conversion of xylose to furfural. As a continuation of this effort toward pentose utilization, the research reported in this study represents the next step in developing a suitable process for the production of furfural, and also demonstrates the practical aspects of microkinetic studies. Based upon the economic processing conditions given here, a pilot plant has been designed and constructed. Work is continuing on the pilot-plant level where the associated technical problems in converting dilute pentose solutions to furfural are being studied.

The information presented here will be of value to those people who are interested in the general question of carbohydrate utilization. For the wood-using industries that already possess pentose streams, this data may be of direct utility in evaluating the possibility of producing furfural.

The units shown in Figures 2 and 3 were chosen to facilitate experimental design and subsequent economic comparisons, hence requiring a word of explanation. The concentration units are stated in terms of the total solids to the solution. These solids contained 44.0 percent of xylose, 12.0 percent of glucose, 9.0 percent of lignin, and 3.85 percent of ash, the remainder being unidentified. A portion of the unidentified material was acetic acid. The acidity definition in particular may seem somewhat unorthodox, since it is expressed in percent sulfuric acid based on the solids (not including the acid). As a consequence, the effective catalyst concentration increases as solids concentration increases. Most of the acid is required to overcome the buffer capacity of the solutions, which is proportional to the solids content.

Comparison of the yields shown in Figures 1 and 2 reveals that the effects of varying temperature and concentration are similar. The yields obtained from the commercial solution (Figure 2) at high acidities are from 3 to 6 percent lower than those predicted from Root's correlation. With decreasing acid-to-solid ratios, yields are decreased similarly to what would be predicted from Root's correlation for acid concentrations below 0.1 N. This effect is due to the large buffer capacity of the solution. An estimate of the buffer capacity obtained by titration of the ash from the hydrolyzate showed that 6.7 pounds of acid per 100 pounds of solids would be neutralized before primary hydrogens of the surfuric acid became available for catalytic activity. Yields are very small below this acid concentration.

The presence of acetic acid does not have an appreciable effect on the reaction rate or yield of furfural. Because of the small ionization constant of acetic acid, a solution more concentrated than 3.2 N is required to produce catalytic activity that is comparable to a 0.01 N sulfuric acid solution. Thus, when sulfuric acid is present as a catalyst, the increase in hydrogen ion content caused by the acetic acid is negligible. Glucose can have a detrimental effect on furfural yields. Root (15) has shown that at low temperatures this reduction in yield can amount to as much as 17 percent. At the temperatures and concentrations used to obtain the data in Figure 2, however, it is estimated that the presence of the glucose accounts for a reduction in yield of less than 1 percent. The results of the study with the commercial hydrolyzate have proved that there is no important reduction in furfural yield due to extraneous materials in the solution.

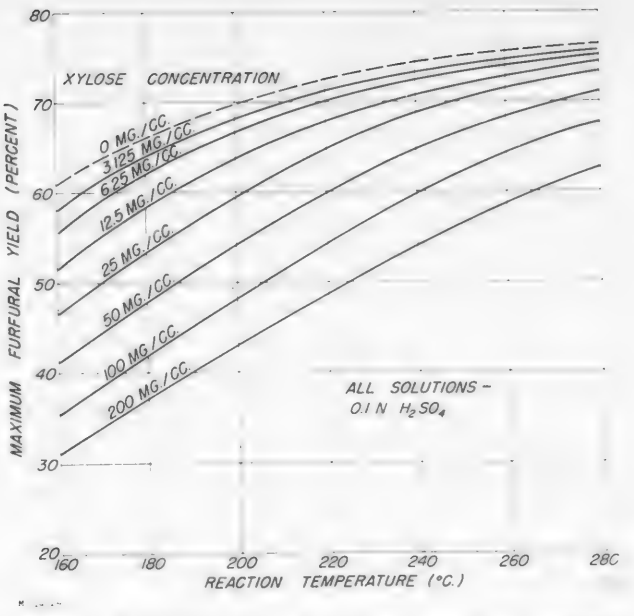


**Fig. 1.—Maximum furfural yields at various initial xylose concentrations and reacting temperatures. Curves apply to all sulfuric acid concentrations greater than 0.1 N.**

## General Process Considerations

The foregoing discussion shows that impure pentose solutions derived from wood can be processed to give yields of furfural in excess of 40 percent. Thus, 2.5 pounds of xylose are used for each pound of furfural produced. The value of xylose, an important factor in the economic picture, is difficult to estimate. In the case of byproduct solutions, many of which cause pollution problems, the cost may be nil or even negative. The cost of xylose in the form of pentosan in a high-pentosan-content hardwood at $9.00 per cord delivered is approximately 1.7 cents per pound if the total cost of the wood is charged to the xylose. The cost of hydrolysis and accompanying losses brings this cost to 3.3 cents per pound of xylose in solution, or 8.3 cents per pound of furfural produced. This high cost of raw material makes it impractical to consider wood as a furfural source if furfural is the primary product. In any process, however, that utilizes the total carbohydrate fraction of the wood and the hemicellulose fraction bears only its proportionate share of raw material cost, the picture is much brighter. If the xylose fraction assumed to bear one-third of the raw material costs, the cost of xylose in solution is estimated at 2.3 cents per pound. This estimated cost includes all manufacturing expenses for producing a solution similar to that previously mentioned. Special pressing equipment is necessary to obtain high yields of xylose at the concentration level of 6 percent. In solution with the xylose are appreciable amounts of glucose and acetic acid. These components might have additional value but bear no portion of the one-third prorated raw material cost, all of which is charged to the pentose.

Most of the furfural marketed annually in the United States is sold in large contract lots at a price probably close to the quoted market price, which was 11 cents per pound f.o.b. plant in January, 1959. The plant size chosen for this evaluation was one with a production capacity large enough to warrant consideration in contract negotiations concerned with its entire output and yet not so large as to create a risk of flooding the market. Accordingly, one with a capacity of 15,000,000 pounds of furfural per year was chosen. A hydrolysis plant capable of supplying a volume of solution adequate for that output would need to have a rated capacity of approximately 300 tons per day of hardwoods. Hardwood residues are available in sufficient quantity at several locations in this country.

The most important production costs, other than xylose, are acid and process steam costs. Increasing the acidity raises yields significantly at low acidity levels, but the effect begins to level off in the range of 12 to 16 pounds of acid per 100 pounds of solids. This increase also results in decreasing the reactor size, but this has little effect on the overall plant cost unless very complicated mechanical-type reactors were being considered; such reactors are not deemed necessary. The economic acid-to-solid ratio is determined very closely by balancing higher acid cost against greater product return. The optimum acid level is dependent on the other conditions of operation but is approximately 13 pounds of acid per 100 pounds of solids, which amounts to 0.80 pounds of acid per pound of furfural produced.

The importance of incorporating efficient methods of heat utilization into the plant design is apparent. The yields of furfural increase with decreasing xylose concentration and increasing temperature. Decrease in sugar concentration results in a nearly proportional increase in plant size and increased steam consumption. Increase in reaction temperature results in decreased reactor size, an inconsequential saving in overall plant cost, and increased steam consumption. Yields are increased at the expense of higher process steam costs and plant investment. The necessity of high heat efficiency is appreciated when one considers the ultimate steam cost when no heat recovery is assumed. To process a 2.5 percent xylose solution in this way would require approximately 60 pounds of steam for each pound of furfural produced at a cost for steam of 4.2 cents.

The recovery of heat is complicated by the bad fouling character of reacting sugar solutions, which requires that the plant be designed to transmit heat only across surfaces that are not contacted by the reacting solution. The bad fouling characteristics of this solution are inherent, depending on the xylose and not upon extraneous components. Maximum yields of furfural occur at approximately 3 xylose half-lives, that is, when about 85 percent of the sugar has disappeared. At this point in the reaction, a solids accumulation amounting to about 25 percent by weight of the original sugar has appeared in the solution.

The nature of these solids depends on the temperature at which the reaction is being performed. At temperatures of 350° F. and below, they are soft, oily-like materials and at higher reaction temperatures appear as hard granules. Presumably this difference is due to the degree of polymerization. The solids are undoubtedly formed throughout the bulk of the solution when it is reacted at isothermal conditions. Because the hard, granular material is not adherent to metal, it would seem that high-temperature processing might be better than operation at lower temperature ranges where the material is soft and ad-

Table 1.—ESTIMATED COSTS FOR PRODUCING ACETIC ACID AND FURFURAL FROM A HYDROLYZATE SOLUTION

| | | Furfural Only | | Furfural and Acetic Acid | |
|---|---|---|---|---|---|
| Estimated plant cost | | $ 427,200 | | 1,115,000 | |
| Annual production—lb. | | | | | |
| Furfural | | 15,000,000 | | 15,000,000 | |
| Acetic acid | | | | 6,752,000 | |
| | | Annual requirement | Dollars per year | Annual requirement | Dollars per year |
| Direct production costs | | | | | |
| 1. Raw materials | Unit cost—$ | | | | |
| Xylose—lb. | 0.023 | 34,000,000 | 782,000 | 34,000,000 | 782,000 |
| $H_2SO_4$—lb. | 0.01 | 8,300,000 | 83,000 | 8,300,000 | 83,000 |
| 2. Utilities | | | | | |
| Steam—Mlb | 0.70 | 220,000 | 154,000 | 571,000 | 399,700 |
| Water—Mlb | 0.03 | 666,667 | 20,000 | 2,000,000 | 60,000 |
| Electricity—K. W. H. | 0.0064 | 1,792,000 | 11,500 | 1,792,000 | 11,500 |
| 3. Operating labor—Hr. | 2.50 | 24,000 | 60,000 | 32,000 | 80,000 |
| 4. Supervision—10% of operating labor | | | 6,000 | | 8,000 |
| 5. Payroll overhead—15% of labor and supervision | | | 9,900 | | 13,200 |
| 6. Maintenance—10% of plant cost | | | 42,700 | | 110,000 |
| 7. Supplies—15% of maintenance | | | 6,400 | | 16,500 |
| Total direct production cost | | | 1,175,500 | | 1,563,900 |
| Indirect production costs | | | | | |
| 1. Technical and analytic services | | | 30,000 | | 45,000 |
| Fixed costs | | | | | |
| 1. Depreciation—10% of plant cost | | | 42,700 | | 110,000 |
| 2. Local taxes—1% of plant cost | | | 4,300 | | 11,000 |
| 3. Insurance—1% of plant cost | | | 4,300 | | 11,000 |
| Total production cost | | | 1,256,800 | | 1,740,900 |
| Manufacturing expense | | | | | |
| 1. Annual cost of raw material | | | 865,000 | | 865,000 |
| 2. One month's operating expense | | | 39,200 | | 58,300 |
| 3. Two weeks' raw material cost | | | 33,000 | | 33,000 |
| 4. Plant investment | | | 427,200 | | 1,150,000 |
| 5. Capital investment (2+3+4) | | | 499,400 | | 1,241,300 |
| 6. Total annual production cost | | | 1,256,800 | | 1,740,900 |
| 7. Sales expense—5% of 6 | | | 62,800 | | 87,100 |
| 8. Administration expense—1.5% of 5 | | | 7,500 | | 18,600 |
| Total manufacturing expense (6+7+8) | | | 1,327,100 | | 1,846,600 |
| Break-even price for furfural[1]—¢/lb. | | | | | |
| Manufacturing expense/15,000,000 | | | 8.85 | | 8.71 |
| Annual product value[2]—dollars | | | 1,650,000 | | 2,190,200 |
| Payout time—years | | | | | |
| Capital investment/annual profit | | | 1.55 | | 3.61 |
| Return on investment after taxes[3]—percent | | | | | |
| (100) Net profit/capital investment | | | 31 | | 13.3 |

[1] Acetic acid credit—8¢/lb.
[2] Furfural price—11¢/lb.
[3] Income tax at 52 percent.

herent. A non-isothermal reactor with heat being supplied to the solution as the reaction proceeds would appear to be a most unsuitable design. The hot walls would promote increased activity in the region of the wall and probably result in fouling of the equipment. The use of direct-injected steam for heating, followed by processing in a holding reactor, would be preferable. It would not be necessary to transfer heat across the reactor walls, and fouling would simply result in decreased capacity. The walls of the reactor would be cooler than the reacting solution, just the reverse of the previous case.

The heat supplied as direct-injected, high-pressure steam cannot be recovered, since it is at the highest temperature in the process. With proper plant arrangement, however, the high-pressure steam used at this point can satisfy the total steam requirements of the process, including the recovery section. By selecting a recovery process in which low-pressure steam can be utilized, the cost of heat required for the complete process can be kept within economical limits.

## Choice of Recovery Process

Among the various methods proposed for the recovery of furfural from aqueous solutions are solvent extraction (11, 16), distillation, and selective absorption on solids (3). For the particular process under study, distillation appears the most practical when, as already pointed out, it is necessary to utilize the heat supplied to the reactor section to accomplish the recovery. Also, furfural has a high relative volatility, greater than 6.0 in dilute aqueous solution, which permits economical stripping of the bottoms concentrations below 0.01 percent. The furfural-water system has an azeotrope of 35 percent furfural at atmospheric pressure. Recovery must be carried out in two towers (Figure 4), an azeotrope tower and dehydrating tower. The azeotrope can be broken by condensing the solution, the condensate separating into two phases, one containing 18 and the other 84 percent of furfural. The dilute phase is returned to the azeotrope tower as reflux, and the furfural-rich phase is passed to the dehydrating tower, where it is concentrated to anhydrous furfural. An extensive experimental study on the recovery of furfural by distillation has been made by Brown and Associates (2).

The hemicellulose material from which xylose is obtained often has a high acetyl content, and xylose obtained by the hydrolysis of such material is accompanied by relatively large amounts of acetic acid. The ratio of xylose to acetic acid is conservatively estimated as 4 to 1 for most hardwoods. No decomposition of acetic acid occurs during the reaction of xylose to furfural; consequently, the relative amount of furfural to acetic acid in the solution charged to the recovery unit is approximately 2 to 1.

As well as considering the recovery of furfural, it is important to examine the possibility of simultaneously recovering the accompanying acetic acid. In Figure 4, the bulk of the acid present in the feed leaves with the stripped solution from the bottom of the azeotrope tower at nearly the same concentration level as in the feed entering the recovery unit. The acetic acid could be recovered from this stream by stripping but because of its low volatility and low concentration this method is impractical.

A method of extracting acetic acid from aqueous solutions using furfural as the solvent has been proposed (17, 18). This method is claimed to be economical at 1.0 percent acetic acid concentrations (6), in which case recovery costs of both furfural and acetic acid could be carried entirely by the acid. Figure 5 shows a process scheme using this proposed solvent extraction recovery method for simultaneous recovery of furfural and acetic acid.

The dilute feed solution of xylose and acetic acid is preheated and brought to the reactor temperature by the injection of high-pressure steam. Following reaction, the solution is flashed to supply heat to the azeotrope column and incoming feed. The solids are removed and the solution is cooled before being charged to the extractor.

In the extractor the dilute solution of furfural and acetic acid is extracted with a stream of cool anhydrous furfural. The raffinate, consisting of 7 to 9 percent of furfural and a small amount of acetic acid, is charged to

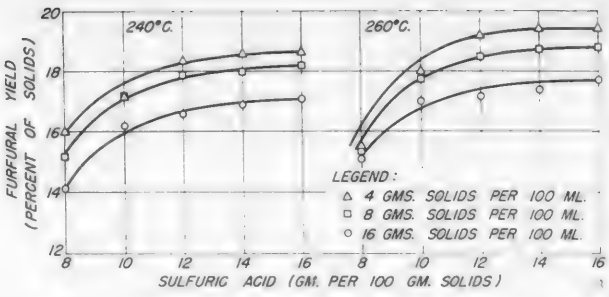
240°C.
260°C.
FURFURAL YIELD (PERCENT OF SOLIDS)
LEGEND:
△ 4 GMS. SOLIDS PER 100 ML.
□ 8 GMS. SOLIDS PER 100 ML.
○ 16 GMS. SOLIDS PER 100 ML.
SULFURIC ACID (GM. PER 100 GM. SOLIDS)

Fig. 2.—Maximum yield of furfural as a function of the acidity at various solids concentrations.

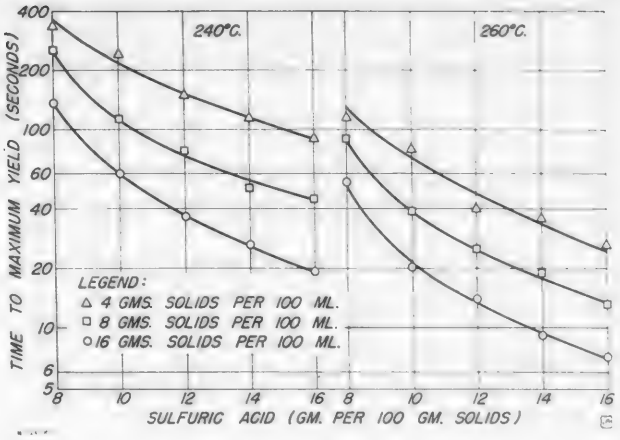
240°C.
260°C.
TIME TO MAXIMUM YIELD (SECONDS)
LEGEND:
△ 4 GMS. SOLIDS PER 100 ML.
□ 8 GMS. SOLIDS PER 100 ML.
○ 16 GMS. SOLIDS PER 100 ML.
SULFURIC ACID (GM. PER 100 GM. SOLIDS)

Fig. 3.—Time at which maximum yield of furfural is reached as a function of acidity at vairous solids concentrations.

the azeotrope tower for recovery of the furfural in a system similar to that employed in Figure 4. The extract stream, containing approximately 10 percent of water, 2.5 percent of acetic acid, and 87.5 percent of furfural, is charged to the dehydrating column, where the water is removed. The anhydrous mixture of acetic acid and furfural is then charged from the dehydrating column to an acid column, where the acetic and other nonvolatile acids are separated overhead, with anhydrous furfural in the bottoms. The bottoms stream is divided, so that a portion leaves the system as product and the remainder is recirculated for use as solvent.

Table 1 presents estimated production costs based on a solution of the composition previously given for producing furfural by each of the two process schemes shown in Figures 4 and 5. These estimates show that the plant producing only furfural is a much more profitable plant than the plant producing both furfural and acetic acid. Although this is true for the particular solution being considered, if the feed stock contained 2 percent of acetic acid the rate of profit return of the two plants would be approximately equal. Restricting the present considerations to solutions generated from the mild hydrolysis of wood, it can be concluded that the return from the process recovering only furfural is much higher than that of the process recovering both furfural and acetic acid despite the fact that there is no acetic acid raw material charge.

## Process Economics

Once the process scheme shown in Figure 4 was selected as an economical method of utilizing the solution produced from wood by prehydrolysis, it was necessary to evaluate accurately the probable operating conditions for this plant. This was done to obtain the information necessary to design a pilot preheater and reactor for a study of the feasibility of the proposed plant. These calculations were based on a plant with a fixed annual production rate of 15 million pounds of furfural. Thus the feed quantity varied depending on reaction conditions and efficiency of recovery. The rate-yield data shown in Figures 2 and 3 were used and, where necessary, these data were interpolated and extrapolated, using Root's correlation.

For purposes of calculation, the process was considered in two parts—the recovery and the reactor section. At a given concentration and enthalpy of feed to the azeotrope tower, the optimum cost of operating the recovery section is fixed. Calculation of this economic optimum is found by considering the operating costs for the individual towers. The type of calculation used is indicated by the following summary.

## Summary and Conclusions

For the azeotrope tower the size, cost, and process requirements were determined as functions of feed concentration, feed temperature, reflux ratio, and recovery efficiency. The method of calculation was straightforward. The Ponchon method was used to determine plate requirements, and heat exchangers were optimized relative to velocity and terminal temperature differences. The calculations were extensive and detailed. Seven feed concentrations were used, ranging from 1.0 to 6.5 percent of furfural. Feed temperatures varied from 60° F. to saturation temperature in six increments. Reflux ratio varied from 1.05 to 4.0 times the minimum reflux ratio at 10 levels. Four recovery efficiencies, 90, 95, 97, and 99 percent, were assumed. The optimum cost for a particular feed condition was selected by comparing the calculated costs at the various reflux ratios and recovery levels.

It was found that the azeotrope

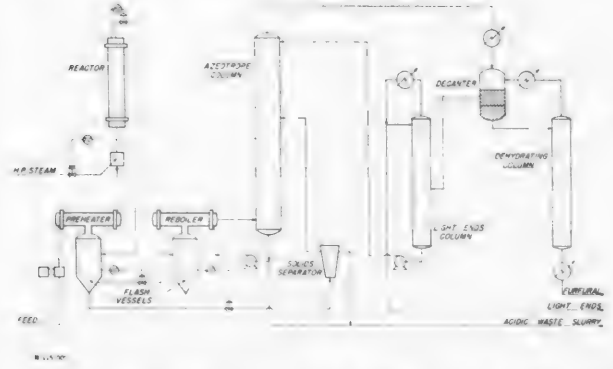


Fig. 4.—Flow sheet—furfural from aqueous xylose solutions.

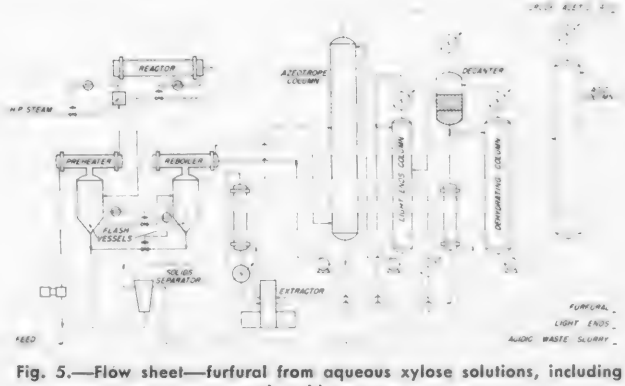


Fig. 5.—Flow sheet—furfural from aqueous xylose solutions, including acetic acid recovery.

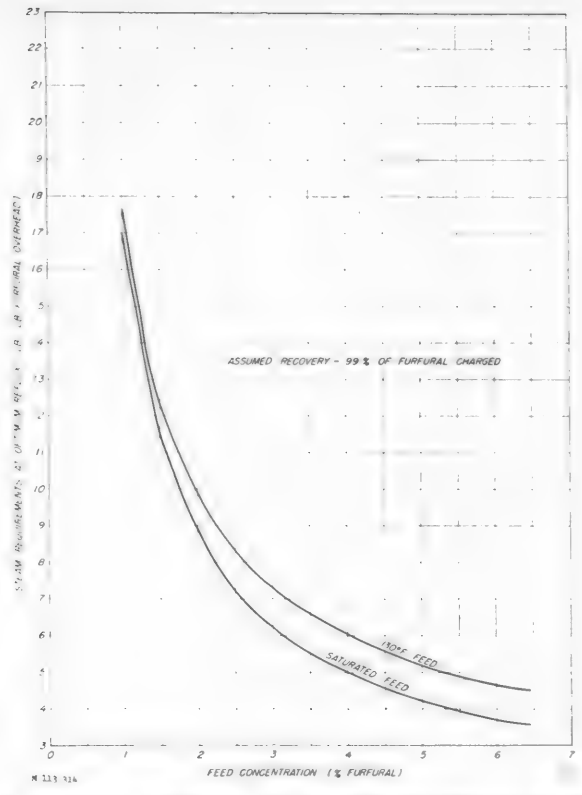


Fig. 6.—Steam requirements for the azeotrope tower at optimum reflux and various furfural concentrations.

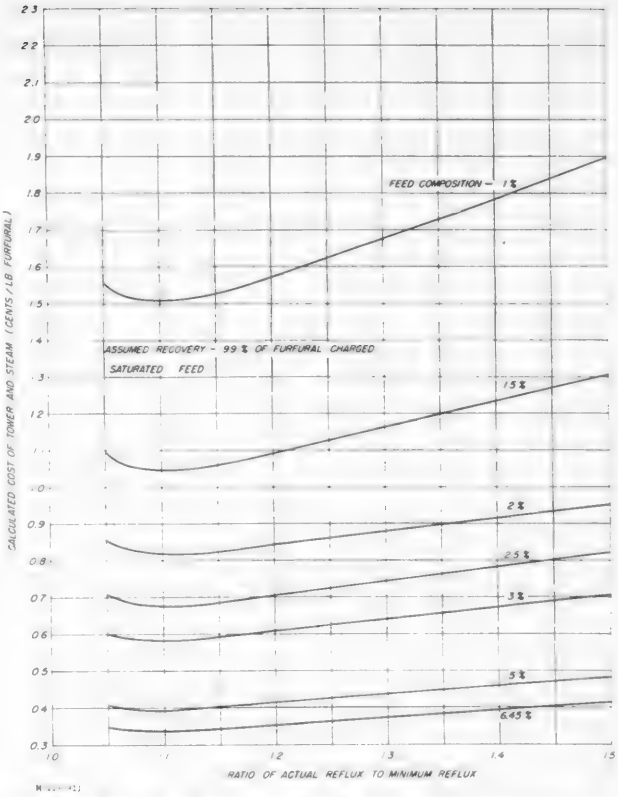


Fig. 7.—Effort of reflux ratio on total cost for the azeotrope tower.

tower, including its auxiliary equipment, easily was the most important item in the plant. This equipment accounts for about 50 percent of the total installed plant equipment cost, and the tower uses approximately 11 times more steam than is used by the other two columns combined. Heat requirements for the azeotrope tower are, of course, very dependent on feed concentration. This is illustrated by Figure 6, which shows steam requirements at optimum reflux levels for various feed concentrations. The effect of reflux ratio on the total cost curve for the tower is shown in Figure 7. The curves indicate that sizable variations from the optimum can be tolerated without seriously affecting the processing costs. This allows considerable flexibility in tower design.

The diameter of the azeotrope tower, at a fixed furfural capacity, varied twofold over the entire feed concentration range of 1.0 to 6.45 percent. Actual plate requirements varied from 35 to 60 at the 99 percent recovery level. Most of these plates are in the stripping section. At a feed concentration of 1.0 percent and a recovery of 99.0 percent, the bottoms concentration is 0.01 percent furfural. It proved to be economical to recover at least 99 percent of all furfural charged, regardless of feed concentration. The tower size for the plant design on which the figures of Table 1 are based is 64 inches in diameter by 60 feet high with 40 plates; the estimated installed cost is $56,000.00

Having established the process requirements and costs of the recovery section as a function of feed concentration and enthalpy, an economic analysis of the entire process was done with an electronic calculator. The hydrolyzate was assumed to enter the process at 100° F. At fixed reactor temperature, catalyst acid concentration, and crude xylose feed concentration, the operating conditions for the entire plant were fixed by the added restriction that all equipment be designed to the economic optimum. The entire heat requirement for the azeotrope tower was considered to be supplied from the reactor product, the remainder of the available heat being recovered in the preheater.

When operating in this manner it is apparent that, if the heat requirement of the azeotrope tower is low, the outlet temperature of the preheater aproaches the chosen reactor temperature. The calculation program included an integration to compute the extent of reaction occurring in the non-isothermal preheater. These values could be compared for the various operating conditions. A good criterion for establishing the allowable amount of reaction occurring in the preheater will not be available until further experimental work is completed.

The important results of the process economics calculation are summarized in Figure 8, which shows the return on investment when processing solutions of various concentrations at the three parametric temperature levels. The profit return values shown are for

Table 2.—RETURN ON PLANT INVESTMENT AT VARIOUS RAW MATERIAL COSTS

| Process | Xylose cost Cents per lb. | Manufacturing expense Dollars per year | Break-even price of furfural Cents per lb. | Payout time[1] Years | Return on investment after taxes[2] Percent |
|---|---|---|---|---|---|
| Furfural only | 0 | 504,500 | 3.36 | 0.44 | 117.1 |
| | 1 | 862,700 | 5.75 | .61 | 78.3 |
| | 2 | 1,219,900 | 8.13 | 1.15 | 41.7 |
| | 2.3 | 1,327,100 | 8.85 | 1.55 | 31 |
| Furfural and acetic acid | 0 | 1,024,000 | 3.22[3] | 1.01 | 47.6 |
| | 1 | 1,382,800 | 5.61 | 1.47 | 32.6 |
| | 2 | 1,738,900 | 8.0 | 2.73 | 17.6 |
| | 2.3 | 1,846,600 | 8.71 | 3.61 | 13.3 |

[1] Furfural price, 11 cents per pound.
[2] Income tax at 52 percent.
[3] Acetic acid credit, 8 cents per pound.

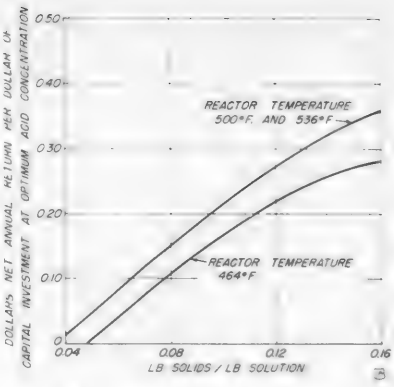


**Fig. 8.—Net annual return on investment for plant operation at various solids concentrations and temperature levels.**

the optimum acid concentration, which varies only slightly from 12 to 14 pounds of sulfuric acid per 100 pounds of solids. The cost of xylose was assumed to be 2.3 cents per pound regardless of the concentration. Figure 8 indicates that the most concentrated solutions of xylose are the most profitable, and that no optimum occurs over the concentration range studied. When considering this fact, it should be remembered that the criterion used was net return on investment and not net return on a particular quantity of solution. If the latter criterion was used, an optimum would occur. An optimum reactor temperature does exist at about 500° F. This applies only to the plant design being considered (Figure 4). If the heat leaving the system with the fluid from the azeotrope still could be partially recovered, the optimum reactor temperature would be higher.

The effect of the cost of xylose on return on investment is shown in Table 2. This illustrates the large advantage gained by decreasing xylose cost. Although it has been assumed throughout the previous discussion that the xylose cost was 2.3 cents per pound, this is a very conservative figure. In an integrated chemical plant utilizing the entire carbohydrate fraction of the wood for chemical raw material, it is conceivable that the xylose cost would be 1 cent per pound, in which case the return on investment would be increased twofold. In cases where xylose solutions are available as a waste material at no cost, the increase in the return on investment is threefold. It is also evident from Table 2 that, although the attractiveness of acetic acid recovery is increased as xylose cost is decreased, the plant that does not recover acetic acid always gives the greater return on investment.

In a plant where pentose solution is obtained by the hydrolysis of wood, it would be advantageous to maintain the highest possible concentration of xylose in solution. This is assumed to be from 6 to 7 percent of xylose. The reactor should be operated at 500° F. with a sulfuric acid catalyst concentration of approximately 14 pounds of acid per 100 pounds of solids. The acid requirement may be expected to be highly variable, depending on species and other factors. The quantity of acid required for the solution used in the experimental work reported here is thought to be near the maximum. The operating preheater outlet temperature is 290° F., which should be easily attained without fouling.

At the lowest concentration level shown in Figure 8, 0.04 pound of solids per pound of solution or 1.76 percent of xylose, the cost of a plant to produce 15 million pounds of furfural a year is approximately $765,000 with an annual total manufacturing cost of about $1,620,900. For the highest concentration, 0.16 pound of solids per pound of solution, or 7.04 percent xylose, the plant cost is nearly $385,000 with an annual total manufacturing cost of $1,315,000.

The economic optimum values of the process variables selected by the procedure outlined above have been the basis for design of a small pilot-type heat exchanger-reactor unit. This model is being operated to investigate the effects of velocity and design on the fouling and corrosion of the components. It is designed to process 800 pounds of solution per hour in the temperature range of interest. Scale-up to the plant on which calculations are based is 50 to 150 fold, depending on feed concentration. It is of interest to note here that the data given in Figures 2 and 3, the basis of design for the plant prototype, were collected in batch reactors of 0.03 milliliter in volume.

The simple plant illustrated in Figure 4 requires a smaller investment for a fixed plant capacity than any other design that might be considered. The development of a continuous process for the production of furfural was viewed as a high-risk venture. Therefore, this design was used for the purpose of the preceding calculations. There are other designs of interest, however, which if employed would increase the profit return on investment but would also increase the capital investment per ton of furfural. For example, a considerable saving could be accomplished by resorting to multiple distillation for the azeotrope tower. This saving in heat, however, complicates the design of the preheater section, requiring that multiple flash units replace the single unit shown. Limited experimental vapor-liquid equilibrium data necessary for evaluating such designs are available for pressures up to 9 atmospheres (5, 12, 14), and these data have been extrapolated to 20 atmospheres (9).

Speculations on other designs are of little consequence until experimental data on the preheater and reactor section are available. These data will permit selection of the most economic recovery process compatible with permissible operating conditions. From the limited data currently available, it is possible to state that, from among the myraid of chemicals that might be produced from wood, furfural is one that shows good financial promise.

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A COMPARISON OF:

# Three Methods for Determining the pH of Wood and Paper[1]

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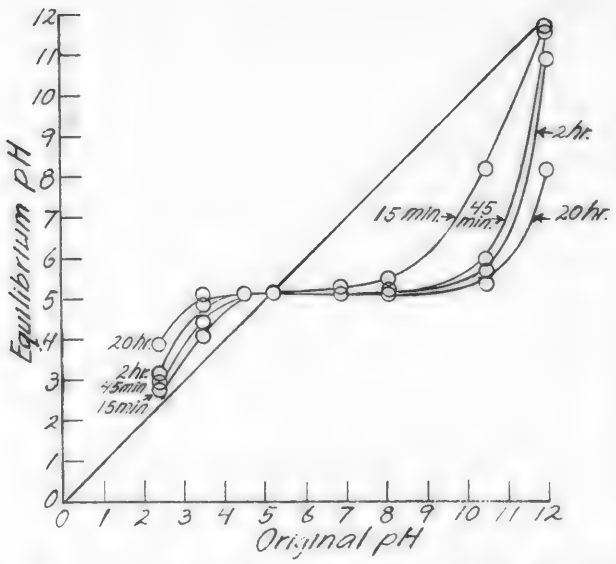


Fig. 1.—Graphic determination of the pH of 1/8 inch thick cross section of sweetgum (4 grams) immersed in unbuffered dilute solutions of sodium hydroxide and of hydrochloric acid (25 milliliters) by determining the pH of the solution that is not changed by the presence of wood after various periods of leaching. The pH of the wood is obtained from the intercept of the graph of the equilibrium pH against the original pH with the straight line reperesenting the unchanged pH.

THE PROCEDURE GENERALLY USED TO determine the pH of wood and paper is to suspend wood, sawdust, or cellulose in the form of pulp in 5 to 10 times as much distilled water by weight, bring it to a boil, then cool it, or merely stir it for various lengths of time without heating, followed by determining the pH of the water extract. Variables not accounted for that could affect the results of this simple test are: 1) variations in the completeness of the extraction of the components of wood or paper that are responsible for determining the pH; 2) variations in the concentration of these components in the water; and 3) variations in the original pH of the water. A further question is: do these tests give the pH of air-dry material as well as the pH of the equilibrium-solid water system?

Campbell and Bryant[2] point out that the solid-water equilibrium system can give a true pH of wood itself only when wood shows a large buffering action on the water. They believe that the pH should be determined by suspending the wood in dilute unbuffered solutions of acids and bases which have different pH values. They further believe that the pH of the solution which is not changed by adding the wood represents the true pH of air-dry wood. They give representative pH values determined in this way for several woods ranging from 2.5 for western red cedar to 6.7 for Mugongo. Unfortunately they give no comparative values determined by the simple water-extraction method.

Ingruber[3] has made similar measurements using only a few different unbuffered solutions with different pH values. He determined graphically the point at which no change in pH occurs from plots of the pH change against the original pH. With use of 40 to 60 mesh wood meal, he found that all the unbuffered solutions, except those solutions with an initial pH of 10 or above, came to a final equilibrium pH in 2 minutes, when 5 grams of wood meal were suspended in 100 milliliters of the solutions. He obtained pH values of 4.4 for spruce, 5.4 for balsam fir, 5.7 for elm, 5.7 for sulfite pulp, 5.4 for Kraft pulp, and 5.6 for cotton.

## Measurements

It would be highly desirable if pH measurements could be made on the surface of solid wood or sheets of paper without reducing them to small particle size. A glass electrode recently has been developed that can be used on semiplastic surfaces. The manufacturer claims that it can be pressed against a surface with pressures up to 100 pounds per square inch, and he recommends it for use on leather and other semiplastic surfaces. Thus it was desirable to determine its suitability for measurements on wood and paper and compare the results with measurements made by the simple extract method and by a slight modification of the methods of Campbell and Bryant[2] and Ingruber.[3]

In order to make the three types of measurements on the same samples and attain equilibrium in a reasonable length of time, cross sections of wood, 1/8 inch thick in the fiber direction, were used. All the specimens weighed approximately 4 grams in the air-dry condition. Multiple thicknesses of air-dry paper, 1.75 inches square weighing approximately 4 grams, were also used in the tests.

Two unbuffered stock solutions were prepared, one containing 1 gram of sodium hydroxide per liter of distilled water and the other, 1 milliliter of 37 percent hydrochloric acid per liter of distilled water. The stock solutions were diluted with distilled water when needed, as follows, to give solutions with the accompanying approximate pH values:

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[1] Presented at the Forest Products Research Society Annual Meeting, Louisville, Ky., Session 13, Division IV (Chemical Conversion A), June 22, 1961. Approved for publication June, 1961.

[2] Campbell, W. G., and Bryant, S. A., Determination of the pH of wood. Nature 147:357.

[3] Ingruber, O. V. 1958. The behaviour of wood and wood constituents as acid-buffering systems. Pulp and Paper Magazine, Canada, Nov. 59:135-141.



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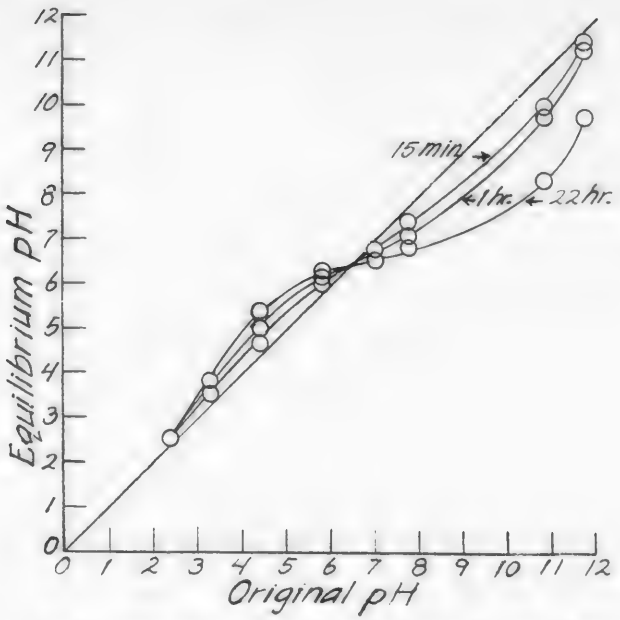


**Fig. 2.—Graphic determination of the 4 grams of ash-free filter paper immerged to 25 milliliters of unbuffered dilute solutions of sodium hydroxide and of hydrochloric acid by determining the pH of the solution that is not changed by the presence of the paper after various periods of leaching. The pH of the wood is obtained from the intercept of the graph of the equilibrium pH against the original pH with the straight line representing the unchanged pH.**

| | |
|---|---|
| 1. undiluted alkali solution, pH | 11.9 |
| 2. diluted (1) 25 to 1 | 10.6 |
| 3. diluted (2) 25 to 1 | 8.0 |
| 4. distilled water | 6.9 |
| 5. 50 ml. of (6) to 100 ml. distilled water | 5.5 |
| 6. diluted (7) 10 to 1 | 4.4 |
| 7. diluted (8) 10 to 1 | 3.4 |
| 8. undiluted acid solution | 2.4 |

Twenty-five milliliters of each of the solutions was pipetted into eight 400-milliliter beakers. The original pH was measured using the type of glass electrode to which pressure can be applied. Matched air-dry cross sections or multiple squares of paper were added to each, taking precautions that the samples were thoroughly wet. After various periods of time, the pH of the solutions in each beaker were determined without removing the specimens. The specimen was removed from the beaker containing only distilled water. Its pH was determined by pressing both electrodes firmly against the surface and then taking a reading. The specimens were then returned to the solution, and measurements again were made after various periods of time.

Experience has shown that erratic contact pH readings may be obtained unless the following precautions are taken:

a) Multiple thicknesses of paper totaling at least 1/16 inch should be used so that the tips of the electrodes can become slightly imbedded under pressure.

b) The measurements should always be made above the fiber saturation point, preferably at a moisture content of 40 percent or more.

c) Precautions should be taken that the electrodes are at right angles to the surface of the sample and that equal firm pressures be applied to both electrodes. This is reasonably well accomplished by adjusting the electrodes in the conventional vertically adjustable holder so that both just touch the horizontally placed sample on a glass plate. Firm downward hand pressure is then applied to the clamp until a perceptible imbedding of the electrodes occurs into the surface. It is suggested that for further studies, a holder for the electrodes be made with a ratchet device that always insures the application of a uniform pressure. It may be found that different pressures are desirable for paper and for soft and hard woods.

The equilibrium pH values determined in the solutions were plotted against the original pH for each solution. The intercept of this reverse S-shaped curve with the straight line representing unchanged pH was determined. Figure 1 gives such a plot for sweetgum and Figure 2 for ash-free filter paper. Figure 1 shows that the same equilibrium pH is obtained after the longer periods of time with several solutions having initially intermediate pH values. In this case, the buffering action of the wood on the solution is high. In the case of the filter paper, shown in Figure 2, the buffering action is quite low. Even after 22 hours of soaking, the curve still intersects the straight line at an appreciable angle. Of the 12 different materials tested, the filter paper showed the least buffering action. All the wood samples, except Sitka spruce and eastern hemlock, gave a high buffering action like the sweetgum shown in Figure 1 as well as the paper toweling and Kraft linerboard. Alphacellulose dissolving pulp sheet and the Sitka spruce and eastern hemlock showed intermediate buffering action. In all cases, the buffering action increased with time.

Table 1 gives a complete summary of the data. In all cases involving contact of the sample with the solution for 0.5 hours or more, the agreement is generally good among the values obtained by the three different methods. Even in the case of the filter paper where the buffering action is low, the agreement is reasonably good.

All data given in Table 1, except part of that for oak, were obtained on originally dry wood. The data for green oak show only slightly lower values than for the originally dry oak. This small difference could be accounted for on the basis that the outward diffusion of the wood components which control pH is more rapid for the green wood than for the dry wood which has to become soaked first.

The data for wood given in Table 1 were obtained entirely on cross sections. A few measurements of the surface contact pH were made on similar thin flat sawn and quarter sawn specimens of Sitka spruce and yellow birch after soaking in water for 15 hours. The spruce gave pH values of 4.7 for both the flat and quarter sawn specimens in contrast to 4.6 for the cross sections. The birch gave pH values of 4.6 for the flat sawn and 4.7 for the quarter sawn specimens in contrast to 4.6 for the cross sections. It appears thus that there is no effect due to the different faces. Equilibrium would, however, be expected to be obtained with the cross sections much more rapidly than with the flat and quarter sawn specimens.

Measurements were made of the contact pH on the green oak boards without wetting. Board number 4 had a moisture content of 83.7 percent and board number 12, 60.6 percent. The former had a contact pH of 4.4 and the latter 4.1. The surfaces of

both boards were wet with distilled water and after 5 minutes the contact pH was again measured. After wetting, both had pH values 0.2 higher. After 20 minutes, however, the values returned to those for the original green wood.

## Discussion

The simple extraction method using only 5 to 6 times as much distilled water by weight as wood or paper seems to give quite satisfactory pH values when compared to the more fundamentally sound intercept method when the buffering action of the material is appreciable. In the cases where the buffering action is low, such as the filter paper, the method may not give satisfactory results. The deviation of the water extract values from the intercept values does not happen to be great in the case of the filter paper, as shown in Figure 2. This, however, can be attributed to the fact that the original pH of the distilled water varied but little from the intercept value. If the pH of the distilled water had been 5.6, which is quite possible when considerable carbon dioxide is dissolved in the water, the water extraction value might have been significantly lower than the intercept value. The pH of ash-free filter paper, unlike that of the other materials tested, is likely due almost entirely to the presence of a small number of carboxyl groups[4, 5] rather than extraneous water soluble extractives. It is believed that practically all woods will contain sufficient water-soluble material to give enough buffering action after a minimum contact time of 30 minutes in the case of thin cross sections to give reasonably good pH values by the extraction method using a minimum amount of distilled water.

The surface-contact method also gives pH values comparable to the intercept values when the dry specimens are soaked in distilled water sufficiently long to come to equilibrium. This will, of course, require a longer time for flat sawn and quarter sawn specimens than for cross sections. Measurements made on the surface of green oak, well above the fiber saturation point, give slightly lower pH values than on the water-soaked specimens. Further wetting of green oak specimens with distilled water slightly raised the contact pH values, but after allowing 20 minutes for attainment of equilibrium, the pH values returned to the original green values. Green cross sections of board No. 4 containing 83.7 percent moisture upon suspension in 600 percent of distilled water for 2 hours increased in contact pH from 4.4 to 4.9 and green cross section of board No. 12 containing 60.6 percent moisture upon suspending in 600 percent of distilled water increased in contact pH from 4.1 to 4.5. In this particular case, diluting the extractives increases the pH. The intercept method gave values closer to the original green contact values.

It still may be questioned whether the intercept method gives pH values for dry wood. The only one of the three methods that can be used without an excess of liquid present, namely the contact method, can be safely used only at moisture contents greater than 40 percent and preferably above 60 percent. It is hence safe to conclude that the values reported in this paper represent pH values for wood at moisture contents of 60 percent and above, and not necessarily that of dry wood.

Thin cross sections of four different softwoods, four different hardwoods, and multiple thicknesses of four different papers weighing approximately 4 grams each were soaked in 25 milliliters of distilled water and in 25 milliliters of unbuffered dilute solutions of sodium hydroxide and of hydrochloric acid having pH values ranging from 2 to 12. The pH of the solutions were determined after various periods of contact with the samples using a new pressure-type glass electrode. Surface contact pH values were measured on the specimens after their removal from the distilled water. Comparison was made of the pH values obtained, in pure distilled water, on the surface of the specimens removed from the distilled water, and from the intercept of the plot of the equilibrium pH of the various unbuffered solutions against their original pH with the line representing equal original and equilibrium pH values. The values determined in these three different ways are in good agreement when the specimens are allowed to soak for at least one-half hour before making the measurements. The plots show that both wood and paper exhibit a significant buffering action upon the solutions that increases in degree with time and varies appreciably between the different samples.

**Table 1.—pH OF WOOD AND OF PAPER DETERMINED BY THE DIFFERENT METHODS**

| Material[1] | Time of liquid contact, hours | pH from: Aqueous extract | Surface contact | Unchanged solution intercept value | Buffering Action[2] |
|---|---|---|---|---|---|
| Loblolly pine | 0.5 | 5.0 | --- | 4.8 | H |
| do | 1.5[3] | 4.8 | 4.7 | 4.7 | |
| do | 0.5 | 4.8 | 5.0 | 4.8 | |
| do | 1.0 | 4.8 | 4.9 | 4.8 | |
| Douglas-fir | 0.25 | 4.7 | --- | 4.4 | H |
| do | 0.75 | 4.4 | 4.6 | 4.3 | |
| do | 3.0 | 4.3 | 4.4 | 4.3 | |
| do | 20.0 | 4.3 | 4.4 | 4.3 | |
| Sitka spruce | 0.5 | 4.8 | 4.8 | 4.6 | M |
| do | 15.0 | 4.6 | 4.6 | 4.5 | |
| Eastern hemlock | .5 | 5.6 | 5.7 | 5.6 | M |
| do | 1.5 | 5.6 | 5.5 | 5.6 | |
| Oak, Bd. No. 4 | 1.0 | 4.9 | 4.9 | 4.8 | H |
| do (green) | 0.5 | 4.8 | 4.9 | 4.6 | |
| do (green) | 2.0 | 4.6 | 4.9 | 4.6 | |
| Oak, Bd. No. 12 | 1.0 | 4.3 | 4.5 | 4.3 | H |
| do (green) | 0.5 | 4.1 | 4.4 | 4.1 | |
| do (green) | 2.0 | 4.0 | 4.5 | 4.0 | |
| Yellow Birch | 0.5 | 4.9 | 5.0 | 4.7 | H |
| do | 15.0 | 4.6 | 4.6 | 4.6 | |
| Sweetgum | 0.25 | 5.3 | 5.2 | 5.1 | H |
| do | 0.75 | 5.15 | 5.1 | 5.1 | |
| do | 2.0 | 5.1 | 5.1 | 5.1 | |
| do | 20.0 | 5.1 | 5.1 | 5.1 | |
| Yellow Poplar | 0.25 | 5.25 | 5.3 | 5.2 | H |
| do | 0.75 | 5.15 | 5.1 | 5.1 | |
| do | 3.0 | 5.1 | 5.0 | 5.1 | |
| Filer Paper (Ashless) | 0.25 | 6.8 | 6.5 | 6.5 | L |
| do | 1.0 | 6.4 | 6.3 | 6.4 | |
| do | 22.0 | 6.4 | 6.2 | 6.4 | |
| Alpha Dissolving pulp sheets | 0.25 | 5.7 | 5.1 | 5.0 | M |
| do | 1.0 | 5.4 | 5.0 | 5.0 | |
| do | 4.0 | 5.3 | 5.0 | 5.1 | |
| Paper toweling | 0.25 | 6.1 | 5.6 | 5.8 | H |
| do | 1.0 | 5.8 | 5.4 | 5.7 | |
| do | 22.0 | 5.7 | 5.4 | 5.7 | |
| Kraft linerboard[4] | 0.25 | 7.5 | --- | 7.5 | H |
| do | 1.0 | 7.4 | 7.5 | 7.4 | |
| do | 4.0 | 7.3 | 7.4 | 7.4 | |

[1] All samples originally air- or oven-dried prior to tests except oak specimens marked green.
[2] H, high buffering action (see Figure 1); M, medium buffering action; and L, low buffering action (see Figure 2).
[3] Measurements made 6 months prior to all other specimens. Cross sections cut from same board as other loblolly pine specimens.
[4] Linerboard made on Forest Products Laboratory Fourdriner machine at Madison, Wis., a city which has extremely hard water, accounting for the high pH.

[4] McLean, D. C., and Wooten, L. A. 1939. Cation exchange in cellulosic materials. Ind. Eng. Chem. 31:1138-1143.

[5] Sookne, A. M., and Harris, M. 1940. The relation of cation exchange to the acidic properties of Cotton. Textile Research Jour. 10:405–419.

*Gluing Characteristics of:*

# Softwood Veneers and Secondary Western Hardwood[1]

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**The availability and size of softwood timber is bound to dwindle in the future and the prominence of hardwood is, therefore, inevitable. With it will come problems in adhesives. Fortunately, many adhesives primarily used for softwood can be modified for hardwood. The problem necessitates consideration so that proper steps in research may be taken.**

SINCE PLYWOOD'S INCEPTION, DOUGLAS-FIR has been the favored species of the softwood plywood industry in the West. It will no doubt, continue to be because of the abundance, availability, size, strength, durability, and percentage of clear veneer which it produces. Other species, however, are becoming acceptable for plywood due to 1) the phenomenal growth of the plywood industry, 2) the expansion of the plywood industry into the Rocky Mountain region, 3) the lower stumpage costs in relation to Douglas-fir, 4) a more favorable log size, and 5) increased utilization through integration and more efficient logging and forest management practices.

Although such species as pine, spruce, redwood, and cottonwood have been used in plywood manufacture for many years, others such as hemlock, larch, and white fir are only beginning to be used to a great extent.

A considerable amount of effort and research has gone into the development of adhesives that are used primarily in Douglas-fir plywood. As a result there is, today, a broad range of adhesives that will perform excellently in bonding Douglas-fir veneer. Many of these adhesives are used with considerable success to bond species other than Douglas-fir. Some of these species, however, contain certain inherent characteristics, unlike those found in Douglas-fir, which require modifications either in glue formulation or in glue application, such as assembly time level, spread level, or pressing conditions.

## Western Softwoods

**Pine:** Ponderosa pine, sugar pine, and western white pine have been glued successfully with a variety of adhesives including cold-press protein, hot-press protein, urea, melamine urea, and interior and exterior phenolic formulations. Since these pines are less dense than Douglas-fir and, hence, more absorptive, they require approximately 10 percent heavier glue spreads to obtain a comparable level of adhesion. The numerous resin canals in pine provide avenues for the migration of glue to the surface. This causes staining of face veneers, particularly very thin veneers. The excessive penetration of glue can be overcome by an increase of glue viscosity through lowering the water to dry solids ratio, and by provision of longer minimum assembly times than normally practiced in gluing Douglas-fir. Where severe staining is experienced, as in very thin face veneers, it may be necessary to use a colorless nonstaining urea-formaldehyde formulation.

The most troublesome feature, perhaps, encountered in the gluing of pine is its frequently very pitchy nature. In the case of protein adhesives, additional caustic in the glue mix together with minimum assembly times of from 5 to 10 minutes helps to overcome this problem. The glue does not dry out as rapidly as on fir veneer, obviously due to the pitchy character of pine. Freshly cut veneer was easier to glue than veneer that had been stored for some time giving the pitch a chance to migrate to the surface. Also, veneer 3/16 inch and thicker accumulates more pitch on its surface than thin veneer due to the larger amount available for migration during drying. Standard exterior phenol-formaldehyde formulations do a satisfactory job of bonding pitchy pine if minimum assembly times of about 15 minutes are observed.

Pine has a tendency to blister if the press temperatures recommended for Douglas-fir are used with either interior or exterior phenolic formulations. This necessitates lowering the press temperatures 20° to 40°F., and longer press times are then required

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to develop the same degree of cure. Blistering is generally not a problem when hot-press blood glues are used because of their inherently lower curing temperatures.

Compression of sugar pine and white pine under heat and pressure is greater than with Douglas-fir and ponderosa pine, so an allowance should be made for this in veneer thickness. Mixing sugar pine, white pine, and ponderosa pine veneers within the same panel should be avoided since the shrinkage rates of the three species are different. Unless the species are balanced on either side of the center ply, a warped panel will result.

Western white pine is perhaps the easiest of the three pines to glue. Resin canals are not as numerous nor as large as those contained in ponderosa and sugar pine; however, staining and over-penetration may still present a problem in very thin veneers. White pine will no doubt find increased use in the manufacture of plywood in the intermountain regions where it grows in abundance.

**Redwood:** Another species which has been glued with a variety of adhesives for many years is redwood. Excellent adhesion has been obtained with cold-press proteins, hot-press proteins, and exterior phenol-formaldehyde formulations. However, all of these adhesives have one major disadvantage—they are all alkaline by nature and tend to stain redwood a very dark, almost black, color. The action of alkali on the pigments contained in redwood apparently is the cause of the staining. If careful attention is given to the spreading operation to avoid over-spreads, core gaps, and splits, staining should not be a serious problem. As mentioned with pine, a nonstaining, colorless glue line can be obtained by using an extended urea-formaldehyde adhesive. A cold-press protein formulation with a 12½ percent latex addition, based on the wet glue mix, has also been observed to give little or no staining of face veneers and has provided excellent dry-shear adhesion.

Another factor observed in the hot-press manufacture of redwood plywood is the abnormal compression which occurs under heat and pressure. Pressing conditions of 285°F. and 175 psi have accounted for as much as 8 percent compression. No corresponding compression was found in cold-pressed redwood panels. Pressures in the range of from 100 to 150 psi during hot pressing proved sufficient in most cases of redwood gluing.

The lower density of redwood in comparison with Douglas-fir accounts for its more absorptive nature and requires from 8 to 10 percent heavier glue spreads. Like pine, redwood has a tendency to blister and reduced press temperatures are required in the case of phenolic adhesives. Longer press times are then necessary to develop the same degree of cure.

A typical press schedule for 5 ply, 5/8-inch redwood plywood glued with an exterior phenolic adhesive is:

| | |
|---|---|
| Wet Spread | 64 pounds per 1,000 feet double glue line/MDGL (⅛-inch veneer) |
| Press Temperature | 275°F. |
| Pressure | 150 psi |
| Press Time | 7 minutes |

**Western Red Cedar:** The gluing characteristics of western red cedar are similar to redwood; however, staining with alkaline glues is not a serious problem. The inherent low strength of cedar is likely the cause of blisters which frequently develop within the wood itself at press temperatures in excess of 270°F. In certain instances, it may be necessary to drop the temperature somewhat below 270°F. to avoid blistering entirely. For every 10°F. drop in temperature above a minimum of 250°F., the press time must be increased approximately ½ minute to develop the same degree of cure. Excessive compression of cedar under heat and pressure requires a substantial reduction in the pressure employed during hot pressing. Pressures as low as 100 psi have been used successfully with no harmful effects on adhesion.

In addition to lower temperatures and pressures to relieve blistering and compression, higher glue spreads are necessary because of the low density (greater absorption) of cedar compared to Douglas-fir.

**Larch:** Western larch, a species found in commercial quantities east of the Cascade Mountains in Washington, Oregon, Idaho, and Montana, is gaining in use as veneer for plywood manufacture. Its gluing characteristics are very similar to Douglas-fir except for the presence of a white crystalline material found in varying amounts on the surface of the veneer depending on its position in the tree and the drying conditions. This substance, identified as galactan, is a water-soluble sugar which is found in heaviest concentration in veneer cut from the sapwood and outer heartwood of butt logs. High drying temperature may also increase the amount of galactan extracted and deposited on the veneer surface.

Laboratory and field experience in gluing western larch has shown that the bond is adversely affected by very heavy concentrations of galactan. Protein bonds are affected, but to a lesser degree than phenolic bonds. At the present time it is not possible to glue larch veneer containing heavy deposits of galactan with exterior adhesives into plywood which will consistently meet exterior performance requirements.

The effect of galactan concentration on adhesion may be reduced by 1) increasing the caustic in the glue mix by 2 to 3 percent and, 2) lengthening minimum assembly times.

Standard Douglas-fir glue formulations and pressing schedules, both interior and exterior, have given satisfactory adhesion on larch veneer when the galactan concentration is light to moderate.

Studies conducted recently by the Douglas Fir Plywood Association on the gluability of larch veneer with exterior adhesives confirm these findings with regard to galactan concentration and bond quality.

**Sitka Spruce:** Spruce has been glued with conventional plywood adhesives for many years, and satisfactory adhesion most generally has been obtained. The most important consideration in gluing this species is its very absorptive nature—much like hemlock and cottonwood in this respect. Also, the veneer is generally rough consisting of shattered areas that cover at least portions of each sheet. The combination of these two features, absorptivity and roughness, require glue spreads at least 5 to 10 pounds per 1,000 feet double glue line over standard Douglas-fir spreads.

**Rocky Mountain Douglas-fir:** The limited gluing studies which have been conducted to date on Rocky Mountain Douglas-fir were based on direct-fire dried veneer which probably influenced the adhesion results. Adequate exterior adhesion using conventional exterior adhesives was not obtained. A lower order of adhesion was also observed with interior protein adhesives, especially in the heartwood veneer. A brief look at the adhesion on some steam-dried Rocky Mountain Douglas-fir glued with an exterior adhesive, however, gave the appearance of a very good bond. It seems, therefore, if the veneer is properly dried, adequate exterior adhesion can be obtained.

There is considerable interest at the present time in this particular species, and a number of organizations are studying its gluability.

**True Firs:** The true firs, including white fir *(Abies concolor)*, noble fir *(A. procera)*, grand fir *(A. grandis)*, and Pacific Silver fir *(A. amabilis)*, are so similar in appearance and properties that is is difficult to distinguish between them once the bark has been removed. Their gluing characteristics are, for all practical purposes, identical. Although noble fir, grand fir, and Pacific Silver fir have been used as core material in plywood for many years, white fir, which reaches its best development in southern Oregon and northern California, has only recently begun to be used in large quantities in plywood manufacture.

The true firs can be bonded satisfactorily with all glues successfully used on Douglas-fir. One factor which influences the gluing of these species is the frequent occurrence of wet spots in the veneer. This necessitates drying the veneer to very low average moisture contents (less than 2 percent), especially in the case of hot-press manufactured plywood since the development of blisters is more likely if areas of high moisture content exist. As a result of drying to very low moisture content, the true firs are absorptive. For this reason, relatively heavy glue spreads are required—often as much as 70 pounds per 1,000 double glue line on ⅛-inch veneer with resin formulations. Careful attention to maximum assembly times is important, as severe dry-out has been observed to be a major cause of adhesive failure.

**Western Hemlock:** Western hemlock has gained considerable use in the manufacture of plywood in the past 3 to 4 years primarily because of its abundance (115 billion board feet estimated in Oregon and Washington alone). Large quantities are used today in the manufacture of plywood sheathing.

Satisfactory adhesion has been obtained with cold-press and hot-press protein interior glues, and Furafil- and bark-flour extended phenolic resins in both interior and exterior formulations. Among the factors that influence the gluing of hemlock is its extreme variation in surface contour causing areas of dangerously low spreads even at 70 pounds per 1,000 double glue line for ⅛-inch veneer. Veneer roughness is due in part to the lathe knife severing the dense summerwood and at the same time propagating a tear in the softer springwood ahead of the cutting edge. The combination of uneven veneer surface and the presence of wet spots, which require drying to very low average moisture contents (less than 2 percent), necessitates an unusually heavy spread to obtain a satisfactory bond. Higher spreads and careful control of maximum assembly time limits are necessary to reduce the severity of dry-out with resin formulations. Careful control of stock temperature is a further requirement for the same reason.

## Western Hardwoods

Hardwoods native to the western states are being used in rather limited amounts in plywood manufacture at the present time. Plywood operators and the lumber industry in general previously have been able to obtain all of the softwood timber they needed and were hesitant to bother with small hardwood logs growing in scattered areas with lower volumes per acre than the softwoods. Western hardwoods are certain to have far greater appeal in the future as the size and availability of softwood timber dwindles.

Little information is available on the gluing characteristics of many of the western hardwoods. In general, however, they are expected to be similar to many eastern hardwood species.

The terms "hardwood" and "softwood" as used here refer to type of wood only as botanically described and not to any physical characteristics such as density.

**Red Alder:** Red alder is widely used as core stock in furniture manufacturing and has found limited use as veneer in plywood. It is the leading hardwood in the Pacific Northwest and has been glued with a variety of adhesives with excellent results, primarily because of its uniform texture and lack of pronounced grain pattern. Excellent fry time tolerance (pre-cure) compared with Douglas-fir has been noted with hot-press urea-formaldehyde formulations.

A typical press schedule for a three-ply construction of 1/6-inch alder cores faced with 1/14-inch Philippine mahogany and glued with a hot-press urea-formaldehyde formulation is as follows:

| | |
|---|---|
| Wet Spread | 60–63 pounds per 1,000 feet double glue line |
| Press Temperature | 260°F. |
| Pressure | 175 psi |
| Press Time | 4½ minutes (2 panels per opening) |

**Cottonwood and Aspen:** The gluing characteristics of cottonwood and aspen are practically identical. Wide variations in the two woods exist in the density and peeling characteristics which influence their gluability. In general, short assembly times should be avoided, and the glue should be applied at as high a viscosity as practical. The best adhesion has been obtained in range of 15- to 25-minute assembly times with resin formulations. The wood is soft and spongy in nature and, therefore, very absorptive—much like spruce and hemlock, thus requiring heavy glue spreads to avoid a starved glue line condition. Badly warped and twisted veneer should not be used as face stock because of the quick development of checks and cracks. Cottonwood has been glued satisfactorily to pine, hemlock, Philippine mahogany, and birch using exterior adhesives. In general, good quality veneer will produce a good bond with practically every type of glue and gluing process.

**Pacific Madrone and Tanoak:** Pacific madrone and tanoak have been glued successfully in our laboratory using a melamine-urea-formaldehyde adhesive and a protein-latex adhesive. No unusual difficulties were noted in gluing these two hardwoods other than the abnormal shrinkage which occurred in the madrone panels. Panels glued with the melamine formulation passed a 4-hour boil cycle (4-inch by 8-inch test specimen) with no delaminations. Protein-latex glued panels exhibited excellent dry-shear adhesion. Both of these species exhibit a pleasing grain pattern and should find acceptance as veneers for cabinet making.

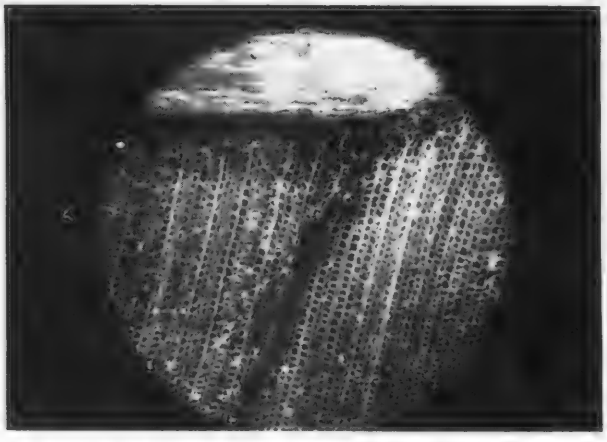
Excellent reports have been published by the Forest Products Laboratory on the veneer cutting and drying properties of both Pacific madrone (Report No. 1766–14) and tanoak (Report No. 1766–15).

## Conclusion

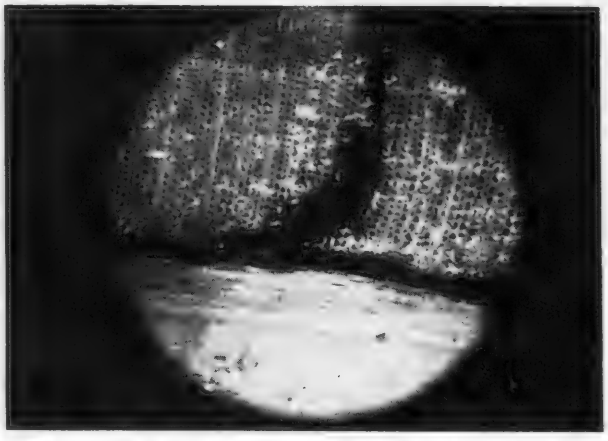
Within any one species, wide variations exist in density, grain configuration, moisture content, and veneer surface characteristics. Gluability will vary accordingly. But, barring certain species characteristics such as the accumulation of resinous material on the veneer surface, most of the species discussed can be bonded equally well with practically all conventional plywood adhesives, providing that the veneer is well dried and density factors which influence absorption are taken into consideration. This is not to say that gluing difficulties other than those mentioned here will not be encountered. For example, gluing difficulty has been experienced with Douglas-fir found growing in areas of southern Oregon and northern California. The high percentage of dense summerwood that occurs in these trees has proved extremely difficult to glue.

However, as in the past, these gluing problems will continue to be solved with the concentrated effort of all the laboratories engaged in research work for the plywood industry.

# Undercured Glue Bonds in Plywood



GLUE-FILLED and tebonded portion of a lathe check indicates a fully cured glue. (photo magnified 10 times.)



UNBONDED but glue-filled portion of lathe check indicates less than complete cure. (Photo magnified 10 times.)

W. V. HANCOCK and P. L. NORTHCOTT
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ALTHOUGH PLYWOOD IS PRODUCED in vast quantities annually, the process of gluing and the evaluation of bond quality remain more art than science. For several years it has been customary at the Vancouver Laboratory of the Forest Products Research Branch to examine experimental plywood under the microscope in an effort to provide explanations for deviations from the anticipated behaviour which were not explained by the factors under study or by inadequately controlled factors such as the specific gravity of the wood. While examining specimens of hot-press phenolic-resin bonded plywood with a wide range of bond quality, including some which were known to be undercured, certain differences were observed which led to an hypothesis that bonds which were undercured at the moment when the platen pressure was released could be recognized then, or at a later date, by examining them under a low-power microscope. The plywood under examination had been manufactured as part of a research program to determine the causes of "casehardening" in plywood[2] of which undercure had been demonstrated to be a major cause. Because the available evidence indicated that undercured bonds, through their influence on the bond quality (as recorded by the industry standard) could be of serious concern to the plywood industry, it was thought that a method of diagnosing the degree of cure of specimens at the time of pres-

**Microscopic evidence indicates three features may be clues to degree of bond cure. These are: 1) migration pattern of glue, 2) cohesive failure within the glue line, and 3) partially glue-filled lathe checks.**

The Authors: William Hancock is a graduate of the University of British Columbia, is a research officer in the plywood unit of the Vancouver Laboratory. Phillip Northcott, also a graduate of UBC, is in charge of plywood research.

[1] Presented at the Pacific Northwest Section Meeting in Bellingham, Wash., Feb. 8, 1960; received by the Journal, May 1961.

[2] Northcott, P. L., H. G. M. Colbeck, W. V. Hancock, and K. C. Shen. Undercure-Casehardening in Plywood. Forest Products Journal, December, 1959.



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sure release would be of value in quality control as well as for research purposes.

In order to test the hypothesis, 60 specimens with a wide range of bond qualities, were chosen from the undercure-casehardening study and examined in considerable detail.

## Material and Methods

The factors used in the gluing study[2] to obtain a wide range of bond qualities from undercured to fully cured were:

1) Species. The species used were chosen to include a wide range of types including softwood and hardwood, resinous and non-resinous wood, woods with hard or soft grain, and woods with a range of densities. The species were black cottonwood (*Populus trichocarpa* Torr. and Gray), Douglas fir (*Pseudotsuga taxifolia* (Poir.)) Britton (both coast-grown and interior-grown), Engelmann spruce (*Picea Engelmanni* Parry), and one of the western Abies (probably *Abies amabilis* (Dougl.) Forb.). All were clear heartwood approximately 0.109 inches thick, and they were chosen from commercial production.

2) Veneer drying history. Veneers were dried at 180° F. or 375° F. or re-dried at 375° F. The veneers dried at 180° F. were dried in a laboratory kiln, while the remaining veneers were passed once or twice (re-dried) through a commercial roller-type dryer at a maximum temperature of approximately 375° F.

3) Veneer moisture content. Veneers were reconditioned to equilibrium moisture content values of approximately 3, 6, and 9 percent in a controlled temperature and humidity chamber.

4) Closed assembly times. Closed assembly times of 1 and 20 minutes were used. Open assembly time was kept to the minimum possible.

5) Press times. 5 and 10 minutes pressing times were used.

6) Sanded and unsanded veneers. One-half of the veneers were sanded before conditioning.

7) Inner and outer glue lines. Panels were pressed two to an opening so that each panel had one glue line that was separated from the press platen by one veneer (outer glue line) and one that had two intervening veneers (inner glue line). This arrangement is illustrated in Figure 1. Since the heat from the platen reaches the glue lines at different times from press closure, there is a probability of different degrees of cure in the two lines, particularly with short pressing times.

Each panel was laid up as illustrated in Figure 1. The lower face veneer

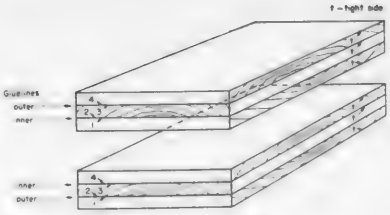


Figure 1.—Arrangement of glue lines in one press load.

was placed with the tight side down (out). The core was placed upon it with the tight side up. The upper face was placed on the core with the tight side up (out). Of the two panels making up a press load, the upper panel had an outer glue line formed between the loose side of the face and the tight side of the core. The inner glue line was between the loose side of the core and the loose side of the face. The reverse was true for the lower of the two panels.

The glue was a standard hot-press phenolic resin, used in commercial plywood manufacture. Pressing was done in a laboratory press in accordance with the manufacturer's recommendations for Douglas-fir exterior-grade plywood, with the exception of those factors such as assembly and press times which were purposely varied to produce a range of bond qualities.

The first examination of an exploratory nature had been carried out on glue lines prepared by sanding the specimen edges with successively finer grades of abrasive paper, the finest being 400 mesh. These were examined with a low-power microscope under reflected light. When it was realized that lathe checks and checks within the glue line were of primary interest as diagnostic factors, it became apparent that detection of these features would be enhanced by the use of a stereo-microscope on specimens prepared with a microtome so that the checks would appear as voids rather than as streaks of debris. To minimize any change in the plywood due to the method of preparing surfaces, it was considered that the usual methods of softening wood prior to cutting with the microtome were undesirable and efforts were made to prepare adequate surfaces without softening the plywood. Two adjacent faces of each block were surfaced with a sliding-block microtome, using only a minimum of soap solution lubricant just prior to cutting. The soap solution was removed during the cutting process so the specimens were, in effect, untreated. To obtain adequately scratch-free surfaces an unused part of the knife edge was used to make the final cut.

For the purposes of this minor investigation the bond quality of each panel was rated by the knife test system set forth in British Standards, 1455:1956, British-made Plywood for General Purposes, British Standards Institution. This system, which rates bonds from 0 to 10, is in essence a wood failure method. The panels used in this minor investigation had all been "hot-stacked" in an oven at 200° F. for 24 hours before knifing. The 60 specimens were chosen from a total of 360 panels to represent a range of bond qualities from 0 to 10. The number of glue lines in each bond quality class was as follows: Class zero—14; Class 1—0; Class 2—8; Class 3—12; Class 4—22; Class 5—10; Class 6—16; Class 7—34; Class 8—40; Class 9—40; Class 10—44.

It was found that the quantity of glue present and the extent of its penetration into the wood could only be determined with confidence on the end grain surface. Therefore, the quality of each bond had to be measured in two different aspects. The measurements relative to the face half of the bond were measured while observing end grain on the face and side grain on the core (Glue line 1, Fig. 1). Measurements relative to the core in the same bond were taken with the

Table 1.—AVERAGE MEASUREMENTS PER GLUE LINE BY BOND QUALITY CLASSES

| Characteristics | Bond Quality Rating | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Lathe Checks:* | | | | | | | | | | | |
| In Glue Lines 1, 2, 4 | 643 | --- | 554 | 616 | 760 | 311 | 654 | 712 | 737 | 635 | 457 |
| Glue in Checks** | 156 | --- | 134 | 106 | 75 | 17 | 69 | 56 | 66 | 36 | 12 |
| Broken-glue Checks | 89% | --- | 77% | 87% | 72% | 100% | 61% | 41% | 27% | 30% | 12% |
| Penetration Unven | 93% | --- | 100% | 83% | 82% | 100% | 75% | 79% | 83% | 78% | 91% |
| Diffused Glue Line | 2% | | 23% | 6% | 12% | --- | 7% | 9% | 9% | 5% | 1% |
| Starved Joint | 7% | --- | 13% | 3% | 6% | 1% | 6% | 2% | 3% | 3% | 2% |
| Discontinuities (Total) | 24% | --- | 22% | 22% | 13% | 11% | 12% | 6% | 5% | 9% | 6% |
| % Grain 5° | 5% | | 8% | 14% | 14% | 6% | 11% | 16% | 10% | 10% | 21% |
| Compression Glue Line | 35% | --- | 11% | 49% | 30% | 66% | 44% | 31% | 40% | 48% | 69% |
| Compression Face or Core: | | | | | | | | | | | |
| Slight | 4 | | 2 | 6 | 5 | 0 | 5 | 7 | 10 | 13 | 8 |
| Medium | 1 | | 0 | 1 | 0 | 2 | 0 | 1 | 2 | 2 | 6 |
| Severe | 0 | --- | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |

* Number of checks multiplied by dpeth of penetration of checks.
** Number of checks containing glue multiplied by depth of penetration of glue.

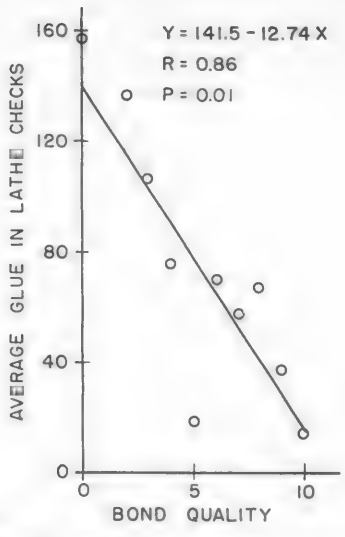


Figure 2.—Relationship between migration of glue into lathe checks and bond quality.

specimen rotated 90° so that end grain in the core and side grain in the face were visible (Glue line 2). Glue lines 3 and 4 were measured at the other core-face interface, glue line 3 being measured in the core and glue line 4 in the face.

### Characteristics Recorded

**Lathe Checks:** The number of checks in each glue line was counted. In the glue lines 1 and 4, the checks in the face veneer were counted; in glue line 3, the checks in the tight side of the core were counted; and in glue line 2 the checks in the loose side of the core were counted. Each check was multiplied by the percentage of total depth of veneer penetrated without regard to the actual length of check. The total for all checks was divided by the number of checks to get an average percentage. The number of checks and this average were recorded.

**Glue in Checks:** In many cases, the liquid glue had penetrated into the lathe checks before it set. The number of checks so penetrated was recorded, together with the depth of glue penetration expressed as a percentage of veneer thickness. This gave a rough quantitative measure of glue that had migrated from the glue line into the checks.

**Broken-Glue Checks:** A check so oriented that it is closed by platen pressure should be repaired if it is infiltrated with glue and conditions are correct for the formation of good bonds. The number of checks containing infiltrated glue was recorded, together with the number of checks that had failed to bond (broken-glue checks). Checks that reopened around the cured glue were considered to be not broken. The lead photo (left) illustrates a rebonded lathe check. The photo on the right shows a check that failed to rebond, although it was glue-filled for some distance from the glue line. This illustrates a broken-glue check.

**Depth of Penetration:** Penetration was expressed in terms of number of cells. This does not express maxima and minima, but rather the general range of depth of penetration over the whole glue line, exclusive of the area immediately adjacent to the lathe checks.

**Uneven Penetration:** The glue line was examined at a magnification of 10 diameters and empirically classified as exhibiting even or uneven penetration of the glue. The areas adjacent to lathe checks were not included in the estimate.

**Diffused Glue Line:** A pale yellow to light brown deposit bordering the glue line and usually extending several cells into the wood denoted a diffused glue line. It was confined to the cell walls and appeared to have spread as a thin liquid. Excessive diffusion of the entire glue into the wood showed as glassy red deposits usually filling the cell cavities. The origin of the yellow deposits is not known, but it may be a fraction of the glue that, under certain conditions, separates out.

**Starved Joint:** A scarcity of glue at the glue line characterizes a starved joint. It was measured only on the end-grain surface, without regard to the presence or absence of glue in the adjacent side-grain surface.

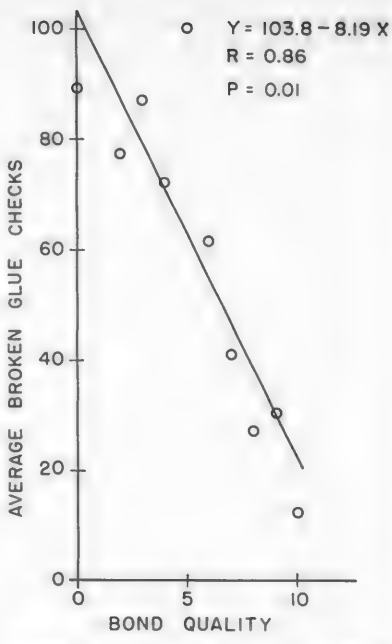


Figure 3.—Relationship between broken-glue checks and bond quality.

**Discontinuities:** These are voids or breaks in the various components of the wood/glue interfaces. Measurements were made in three categories: (a) rough veneer—a void in the glue line caused by roughness of the veneers beyond the gap-filling capacity of the glue; (b) bond ruptured—a cohesion failure within the glue; (c) wood ruptured—a break in the wood external to the glue line but parallel to it.

The figures presented in the various tables represent totals for all categories. In all cases, the major component was that due to bond ruptures (69 percent of the total).

**Percent Grain over 5°:** The amount of side-grain present that met the glue line at an angle of 5° or greater, thus increasing the probability of flow of glue into the cell lumens, was measured on the side grain surface and expressed as a percentage of total length of glue line.

**Compression:** The severity of crushing of the various plies was estimated and expressed as none, slight, medium, or heavy.

An estimate, on a lineal basis, was made of the percent of the wood adjacent to the glue line which had been compressed. This occurred frequently, even though the balance of the ply was

Table 2.—FREQUENCY OF DEPTH OF PENETRATION (Cells) IN BOND QUALITY CLASSES

| Depth of Penetration (Cells) | Bond Quality Rating | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0 | 6 | - | 1 | 1 | 9 | 0 | 5 | 3 | 4 | 2 | 0 |
| 1 | 8 | - | 6 | 7 | 10 | 3 | 7 | 25 | 33 | 25 | 11 |
| 2 | - | - | 1 | 4 | 1 | 2 | 2 | 4 | 2 | 3 | 16 |
| 3 | | - | | -- | ---- | 1 | ---- | 2 | 1 | 5 | 6 |
| 4 | | - | | -- | ---- | 3 | 2 | ---- | ---- | 1 | 8 |
| 5 | | - | | | 2 | -- | | | | 2 | 2 |
| 6 | | | | | -- | 1 | | | | 1 | 1 |
| Over 6 | | | | | - | | | | | 1 | ---- |
| Average depth of glue penetration (cells) | 0.6 | 0 | 1.0 | 1.2 | 1.0 | 2.8 | 1.2 | 1.2 | 1.0 | 1.8 | 2.5 |

uncompressed. Presumably, this was due to the greater plasticity of the wood in the vicinity of the glue line induced by the additional water received from the glue.

## Discussion

**Lathe Checking:** Table 3 shows that the severity of lathe checking varied in the different species, Douglas fir being most severely, and cottonwood least severely, checked. This was probably due partly to species and partly to mill practice.

**Glue in Checks:** From Table 1 (2nd line) and Figure 2 it seems that the amount of glue which left the glue line and entered the checks was an indication of poor bonding, in many cases. A good negative correlation is evident between bond quality and the amount of glue in the checks (Correlation Coefficient 0.86, significant at the 1% level).[3]

**Broken-Glue Checks:** From Table 1 (3rd line) and Figure 3 a strong negative correlation with bond quality is indicated (Correlation Coefficient[3] 0.86, significant at the 0.1% level). It seems logical that poor bonding conditions in the glue within the checks are an indication of similar poor bonding conditions in the main glue line. The lead photos illustrate the differences in appearance of reglued and "broken-glue" checks.

**Depth of Penetration:** Table 2 indicates that there is a tendency for bond quality to improve as depth of penetration increases (based on minima). Interpretation is complicated because the cottonwood specimens, which exhibited the highest bond quality, also show the greatest amount of glue penetration. It is felt that the high average bond quality for cottonwood may be due largely to the low inherent strength of the wood leading to high wood failure readings.

**Uneven Penetration and Diffused Glue Lines:** More than 85 per cent of the glue lines examined were judged to be uneven in penetration. No effect on bond quality was apparent (Table 1).

The presence or absence of diffused glue lines seemed to have no effect on bond quality.

**Starved Joint:** Although a trend is apparent in this factor, it is not consistent throughout the range of bond qualities. This may be due to the low incidence of this defect or to the difficulty in estimating it accurately (Table 1).

[3] The values used were the average for all glue lines within each bond quality class. An analysis based on comparisons with individual readings would yield a weaker correlation.

**Discontinuities:** As might be expected, there is a good correlation between the presence of discontinuities and low bond quality (Correlation Coefficient[3] 0.92, significant at the 0.1% level). The major defect was rupturing within the glue line (Table 1 and Figure 4).

**Percent Grain 5°:** Although this has been suggested as one cause of poor bonds, there was no evident relationship between this factor and per cent wood failure (Table 1).

**Compression Face and Core:** Referring to Table 3, a definite species effect appeared with practically no compression in Douglas fir and the maximum present in the softer species. This was to be expected since the same press pressure was used for all species regardless of their different compressive strengths. There was, however, no apparent effect on bond quality (Table 1).

**Glue Line Compression:** The degree of compression in the vicinity of the glue line was much greater than that throughout the remainder of the veneers, probably due to the plasticizing effect upon the wood of the additional water provided by the glue. Compression occurred in the vicinity of the glue lines with all species but was much more severe in the case of the weaker species (Table 3). There appeared to be no correlation between the degree of compression and the bond quality (Table 1).

## Conclusions

The evidence indicates that it is possible to estimate the degree of cure of hot-press phenolic plywood bonds, at the moment pressure is released, within certain limits, by examining the plywood under a low-power microscope. It is considered that this may be of value to quality control and research personnel in diagnosing bond deficiencies, particularly when these are associated with a sub-standard cure of the bond.

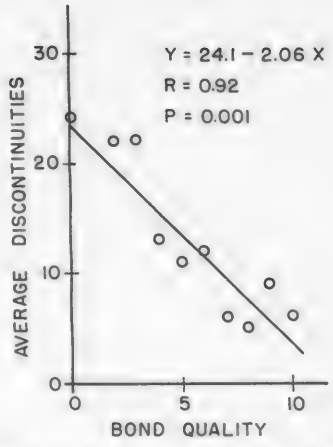


Figure 4.—Relationship between discontinuities and bond quality.

Three features are of particular value for this purpose.

1) The quantity (percentage) of glue which has migrated into the lathe checks is an indication of poor bond. The greater the migration, the more undercured the bond when press time is constant.

2) There is good correlation between discontinuities in the glue line due to cohesion failures and poor bonds. These indicate lack of strength to resist stresses imposed on release of platen pressure.

3) The condition of lathe checks which have been partially filled with glue, particularly those portions of the lathe checks which are approximately parallel to the glue line, is probably the most useful single indicator. When the glue-filled portions are bonded this is evidence that the bond was adequately cured. When the glue-filled portions of the lathe checks are not bonded, but are characterized by the original lathe check gaps remaining through the glue-impregnated wood, this is evidence that the glue was not sufficiently cured to withstand the tensile forces exerted on the incipiently-bonded lathe checks by the spring-back of the veneers.

Table 3.—AVERAGE MEASUREMENTS PER GLUE LINE BY SPECIES

| Characteristics Measured | Species | | | | |
|---|---|---|---|---|---|
| | Interior Douglas Fir | Coast Douglas Fir | Interior Spruce | Abies Species | Western Cottonwood |
| Lathe Checks* Glue Lines 1, 2, 4 | 738 | 884 | 561 | 693 | 236 |
| Diffused Glue Line | 15% | 8% | 2% | 7% | 0% |
| Starved Joint | 7% | 5% | 2% | 3% | 1% |
| % Grain 5° | 14% | 21% | 6% | 15% | 10% |
| Compression Glue Line | 14% | 25% | 57% | 43% | 87% |
| Average Bond Quality | 5.2 | 7.6 | 5.1 | 7.5 | 8.8 |
| Compression Face or Core: | | | | | |
| Slight | 2 | 6 | 22 | 25 | 5 |
| Medium | 0 | 0 | 2 | 3 | 10 |
| Severe | 0 | 0 | 0 | 0 | 2 |

* Number of cheks multiplied by depth of penetration of checks.

**THE ECONOMICS OF:**

# Automatic Lumber Sorting[1]

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British Columbia Research Council,
University of British Columbia,
Vancouver, B. C.

**What conditions are required for profitable use of automatic lumber sorting? Here is an evaluation of partially mechanized and fully mechanized sorters, a comparison of capital expenditures with manpower savings, and an indication of production output and number of sorts required (based on both solid and stickered loads) to justify installation costs.**

THE USE OF AUTOMATIC SORTERS to replace manual labor is very limited, even though lumber sorting normally involves a large amount of physical handling. The British Columbia Research Council has been studying the problem of automatic sorting with two aims in mind. The first is to determine the conditions under which profitable use may be made of presently available sorters. The second is to isolate the expensive component of mechanical sorting in order to provide direction for the necessary advances in design.

Automatic sorters have been denoted as either partially or fully mechanized, depending on the way in which the lumber is handled after sorting. The simple edge-sorter is a partially mechanized machine, producing a rough pile for subsequent stacking and stickering. The fully mechanized machine allows controlled delivery of sorted lumber from trays, pockets, or live bays to a stacking or stickering machine.

On the basis of the direct costs, the partially mechanized sorter does not appear attractive for solid-stacked loads. It is justified for 100 percent stickered loads when the number of sorts is less than 60 or 70 for each 100,000 board feet per shift. If a mill has a conventional chain with a stickering machine, however, it may not be worth changing, since the capital value of the stickering machine would not be saved.

The Authors: J. Charles Clapham, head of the Operations Research Section, holds degrees from Cambridge and London Universities, England. Mr. Lambe, an engineer in the Section, holds degrees from the Univ. of British Columbia and from Stanford.

The fully mechanized sorter can be justified only for outputs of more than 100,000 board feet per shift with a very few sorts. The region of applicability would be greatly increased by a reduction in capital cost or by management willingness to spend more to save a man.

These direct cost comparisons are quoted to indicate the approximate area in which a sorter should be considered. Particular problems of installation or the importance attached to indirect factors not included in our costs may alter the region of attractiveness for any specific sawmill.

## The Sorting Operation

The sorting operation involves four major components: 1) segregating, 2) storing, 3) stacking, and 4) stickering. Lumber arrives from the sawmill with the different sizes and grades intermixed. The pieces have to be segregated into sorts of differing activity (or "busyness"). The lumber has then to be stacked and, if drying is required, stickered. Storage of lumber may occur at one or more stages in the operation in order to allow sufficient pieces to accumulate to justify their subsequent handling.

The variation in activity of the sorts is an important feature of the sorting problem. Normally there are a few busy sorts and a large number of slack ones. Figure 1 shows the proportion of lumber volume accounted for by any given proportion of the active sorts at a number of sawmills. (Load-locations that receive less than a carrier load per week have been considered inactive. They are often kept for mistakes or "freaks" in case, for example, a log of the wrong species is found in a boom.)

Despite the differences in output and number of sorts, the pattern of Figure 1 is similar for all the sawmills. The reason for this may be found by examining the factors that determine the load to which a board will be sorted. The position selected for the border line between one sort and the next is affected by the dimensions, moisture content, or grade of the board and normally is not related to the volume of lumber involved. For example, length subdivisions do not give equal-sized groups but make some sorts more popular than others. Similarly, lumber is not segregated into equal categories for moisture content, but is partitioned into heart and sap to suit the kiln. If the borderlines between the sorts are unrelated to each other and to the volumes of lumber produced, the expected form of Figure 1 can be calculated mathematically. This theoretical curve shows good agreement with the observations. It implies that a lumber sorting system, by its nature, has to handle relatively few busy loads and relatively many slack loads.

[1] A contributed paper approved for publication April 20, 1961.

[2] Clapham, J. C. and T. A. Lambe 1961. An operations research approach to Lumber sorting. For. Prod. Jour. 11(4) 181-184.



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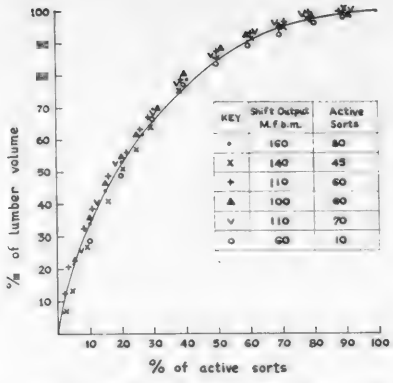


Fig. 1.—Graphic variation in sorting activity; the proportion of lumber volume is accounted for by any given proportion of the active sorts at a number of sawmills.

Table 1.—ASSUMPTIONS MADE IN ESTIMATING SORTING-CHAIN LABOR REQUIREMENTS

| | |
|---|---|
| Pulling Time | 8 seconds per piece |
| Walking Time between Load Centers | 1½ seconds |
| Peak Lumber Arrival Rate | 30 pieces per minute for each 100 M fbm/shift |
| Chain Breaks | Output: 100 M fbm shift. Break at 40% of length. Output: 200 M fbm/shift. Breaks at 10% and 40% of length. |
| Load Arrangement | Busiest at upstream end, decreasing in activity down lumber-line side to the foot of the chain; then starting again on the other side, decreasing in activity to the foot of the chain as before; distribution of activity assumed to be as in Fig. 1. |
| Speed of any Chain Section | 18 feet per minute for each 100 M fbm per shift passing over that section. |
| Stickering Time[1] (where stickering is performed manually) | 6 men per 100 M fbm/shift (16 seconds per piece). |

[1] For machine stickering time and costs, see Table 2.

## Manual Sorting Labor Requirements

To assess the economics of mechanization, the manpower savings must be compared with the capital expenditure. The labor requirements must, therefore, be calculated for both a completely manual system and for any part which remains manual after some sorts are mechanized. Moreover, any comparison made should be among efficient systems of each kind. For example, a high-volume output sorted manually on a single one-speed chain would be relatively inefficient. Significant savings could be achieved relatively inexpensively by breaking the chain to allow speed reductions.

The methods to compute the labor requirements for stacking from a sorting-chain have been presented in an earlier paper.[1] The number of men required depends on the peak arrival rate of lumber, the chain speeds, the load spacing, and the size of lumber. Stickering has been taken as a separate operation to follow stacking. It is performed manually if the lumber volume is low, or by machine if the volume is high. Although some sawmills sticker at the sorting-chain, this is not a common practice. It has advantages in direct costs, but there are off-setting disadvantages to be discussed later. We do not have sufficient evidence to judge between the methods, so we have supposed the more usual practice of a separate stickering operation. Estimates of labor requirements for stacking and stickering have been based on the values listed in Table 1. These are typical of reasonably efficient sawmill practice.

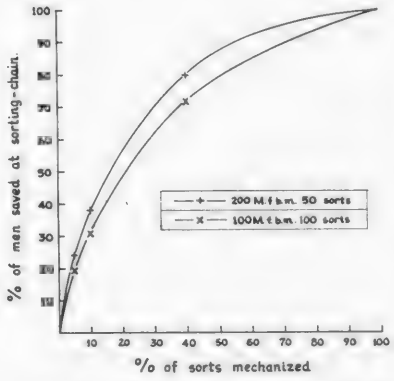


Fig. 2.—This graph shows the percentage of manpower saved on sorting chain corresponding to a given proportion of sorts mechanized.

The effect of mechanizing a proportion of the sorts is illustrated in Figure 2, which shows the proportion of men saved on the sorting-chain. It does not account for the extra labor required to operate the automatic sorter—this is considered later. The proportion of men saved is normally within five percentage points of the volume of lumber mechanized. For example, mechanizing the busiest 40 percent of the sorts would reduce manpower on the sorting chain by between 70 and 80 percent, which compares with 75 percent for the proportion of lumber (Figure 1). The reduction in labor would be at the higher end of this range for higher volume or fewer sorts.

## Automatic Sorter Costs and Labor Requirements

The cost of an automatic sorter largely depends on the extent to which it mechanically controls the flow of the sorted lumber on its way to a stacking or stickering machine.

Partially mechanized sorters segregate the lumber into separate rough piles. The lumber then is manually stacked and, if necessary, stickered, as it accumulates. The simple edge-sorter is the principal example of this class in North America. There is also a Swedish sorter in which overhead chains move the lumber along on skids and drop it into pockets. The capital cost of these sorters is low, about $1,200 per sort, including installation but not land.

Fully mechanized sorters control the flow of the lumber so that it may be fed substantially piece-by-piece to a stacking or stickering machine. Because of the necessity of assembling sorted lumber in packages, the sorter must have storage capacity for each sort. This storage may be provided by trays, pockets, or live bays. Whichever form is used, the relatively high cost is incurred because of the difficulty of retaining control of substantial quantities of unstacked lumber. The cost depends strongly upon the amount of storage provided. With the possible exception of the mechanized edge-sorter with live bays, it normally is not considered economic to provide sufficient storage for full kiln-car loads. The question of the optimum amount of storage and the corresponding best size of package is an important one, but one which will not be evaluated quantitatively here. For the present study, the costs have been based on fully mechanized sorters as normally used to provide solid stacks or stickered packages for later assembly late kiln-car loads. The average installed cost of a fully mechanized sorter under these conditions is about $30,000 plus $4,500 per sort. This excludes the cost of the stacking or stickering machine.

There are systems which lie between the simple edge-sorter and the fully mechanized system. The lumber from a simple sorter may be dropped into wagons, or may accumulate on skids to be transferred by fork-lift truck to a mechanical stacker. These systems require lower capital cost but need extra intermediate handling. There is an additional difficulty in ensuring that the quantity of loose lumber transferred to the stacker is a full load, since surplus partial layers or loads require rehandling. These systems have not been considered in detail in this study.

Table 2 lists the installed costs assumed for automatic sorters and stackers and the estimates of the labor requirements. The labor estimates have been based on a combination of time studies, known manpower at particular sawmills, and manufacturers' estimates. The data presented are our own best estimates after correspondence with six manufacturers.

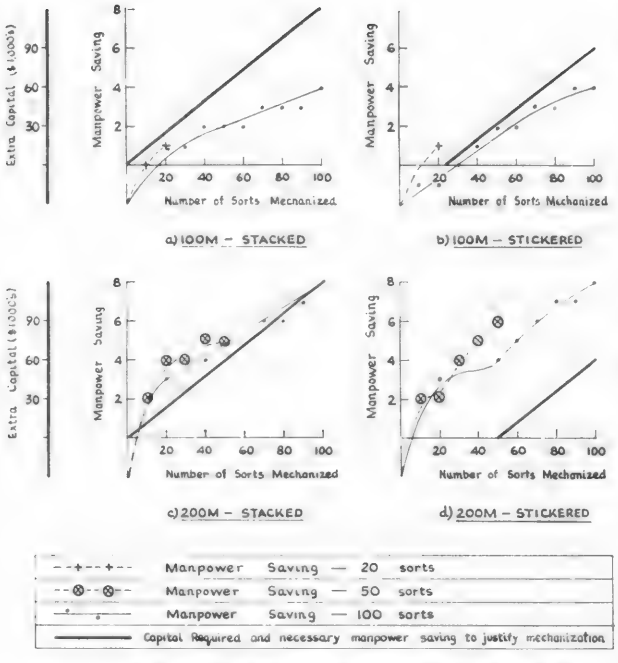
Extra Capital ($1,000's)
Manpower Saving
Number of Sorts Mechanized
a) 100M – STACKED
b) 100M – STICKERED
c) 200M – STACKED
d) 200M – STICKERED
Manpower Saving — 20 sorts
Manpower Saving — 50 sorts
Manpower Saving — 100 sorts
Capital Required and necessary manpower saving to justify mechanization

Fig 3.—A graphic comparison of partially mechanized sorter with manpower savings per shift and capital expenditures is shown.

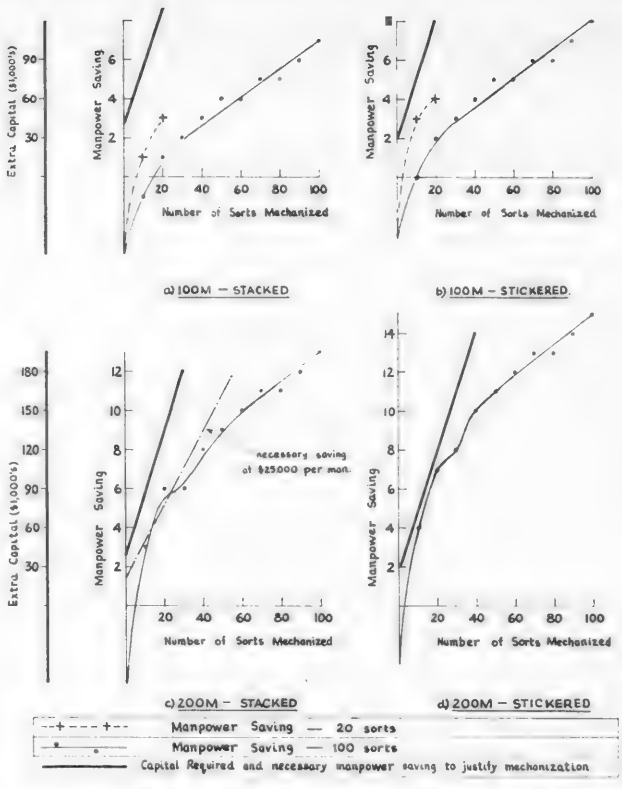
Extra Capital ($1,000's)
Manpower Saving
Number of Sorts Mechanized
a) 100M – STACKED
b) 100M – STICKERED
necessary saving at $25000 per man.
c) 200M – STACKED
d) 200M – STICKERED
Manpower Saving — 20 sorts
Manpower Saving — 100 sorts
Capital Required and necessary manpower saving to justify mechanization

Fig. 4.—A graphic comparison of a fully mechanized sorter with manpower savings and capital expenditures is shown.

## Evaluation of Sorters

The required capital expenditures for both types of sorter have been compared with the resultant manpower saving for a range of sawmill conditions. These cover shift outputs of 100,000 and 200,000 board feet and sorts of 20, 50, and 100 in number, both 100 percent solid-stacked and the 100 percent stickered. The comparisons have been made separately for each type of sorter with the proportion of mechanization increasing in 10-sort increments. A stacking or stickering machine has been introduced when the labor saving justifies the cost.

Figures 3 and 4 compare partially and fully mechanized sorters, respectively, with manual sorting. The manpower saved per shift and the capital required are plotted against the sorts mechanized. Although irregularities occur at points where a man or machine has been added, a smooth curve has been drawn through the points to indicate the trends.

A figure of $15,000 per man has been used to scale manpower to cost. On a two-shift basis, this would mean that the capital would be repaid by labor savings in just under 2 years (excluding any allowance for maintenance and energy costs). Figure 4C also illustrates the effect of using $25,000 per man for comparison. (It may also be interpreted to illustrate the effect of reducing the sorter price in the ratio of 15,000 : 25,000, i.e. by 40 percent.)

At the return on investment indicated by $15,000 per man, mechanization is justified (on the basis of the direct-sorting costs) only when the heavy line of capital cost in the figures is below the light line of manpower saving. Furthermore, mechanization is most favorable where there is the greatest difference between the manpower saving and the capital cost. Further mechanization beyond this level is not justified.

The result for the partially mechanized sorter (Figure 3) may be sammarized as follows:

**Solid-Stacked Loads:** The sorter should not be considered for solid-stacked loads at mills with outputs of less than 150,000 board feet. Above this figure, it would be equally advantageous to divert a proportion of the lumber to a parallel manual chain instead of a sorter.

**Stickered Loads:** The sorter can be considered for stickered loads at any output providing that the number of sorts is less than 60 to 70 for each 100,000 board feet per shift. It will normally be worthwhile to mechanize all the sorts, unless the number is very high.

These calculations assume that a new system is being considered and that there is free choice between a sorter and a manual system (including a stickering machine, if necessary). However, if a stickering machine is already owned, the capital expenditure on it is not saved by changing to a sorter and the comparison is less favorable.

The fully mechanized sorter (Figure 4) can be considered for only the busiest sorts of mills with outputs that exceed 100,000 board feet per shift if the number of sorts is low. It cannot be justified for lower outputs, because the manpower savings are outweighed by the fixed labor and basic capital cost of the sorter.

Figure 5 shows the general characteristics of mill output and sorting requirements where each type of automatic sorter is applicable. Only stickered loads have been considered for partially mechanized sorters (such as the edge-sorter), and only solid-stacked loads for fully mechanized sorters. Figure 5 also indicates the effects of lower sorter cost and of prior ownership of a stickering machine.

### Indirect Factors

Factors other than the foregoing comparison of direct sorting costs may affect the choice of sorting procedure. Chief among these are sorting flexibility, space limitations, and stickering preferences.

**Sorting Flexibility:** The ease with which the load specifications can be changed for different log supplies or market requirements is very important to many sawmill operations. Tray or pocket sorters appear to be as flexible as the conventional sorting chains. However, for some types of edge-sorter, the number of thickness or grade separations cannot be changed easily.

**Space Limitations:** Space limitations may dominate the choice of sorter for saw mills near cities. Tray or pocket sorters require substantially less room than conventional sorting chains. On the other hand, edge-sorters demand not only a long straight space for the conveying slots but also need additional area for storing rough-piled lumber. With simple edge-sorters, large areas are occupied by the manual assembly of loads adjacent to each bay, particularly if the loads are kiln-car size. With fully mechanized edge-sorters, storage is needed for the jumbled piles preceding the stacker.

**Stickering Preferences:** The method of preparation of a load for kiln-drying may be an important factor in the selection of a sorting system. The three methods used are 1) direct assembly of full kiln car loads; 2) preparation of small stickered packages which are later assembled to form full car loads; and 3) preparation of solid-piled loads which are later unstacked and re-assembled into full car loads.

Full-sized loads may be produced directly with partially mechanized sorters by hand stickering and with mechanized edge-sorters by machine. In theory, tray or pocket sorters could be used to produce full-sized loads directly but the cost of the necessary storage in the machine would be prohibitive.

Small stickered packages may be produced by tray or pocket sorters or by a conventional manual system where stickering is performed at the chain. Kiln-car loads of assembled packages have the disadvantage that damage may be caused by misplacement of stickers during handling.

Solid-piled loads may be produced by tray or pocket sorters or by a conventional chain. This system has the disadvantage of introducing an extra handling operation. However, it overcomes the disadvantages of stickered packages and requires less yard storage space before the kilns. It may also permit machine stickering instead of hand stickering, thus producing a higher quality product.

### Direction of Sorter Development

The greatest advance in sorter design would come from a cheaper method of assembling and transporting stacked loads for storage. Sorted lumber may be stored in a machine either as jumbled pieces in a pocket or live bay, or as ordered pieces in a tray. These pieces may then be assembled in packages for subsequent handling. The higher the storage capacity in the machine, the larger the package, and thus the lower the subsequent handling costs. A significant reduction in cost, hence, could be effected by either cheaper storage or cheaper transportation for small packages. The most direct improvement would be a cheaper tray. The indirect approach would be the development of a device for economically moving small lumber quantities—perhaps equivalent to only one or two layers of present loads. Long trays and large packages possibly could be used for the popular sorts with short trays and small packages for the slacker ones.

Since the cost of segregating lumber into jumbled piles is low, no significant reduction in partially mechanized sorter costs can be expected. However, room is sometimes an overriding factor limiting the application of the edge-sorter. Its inflexibility is also a handicap. Compactness and greater flexibility appear to be the areas where improvement to the edge-sorter can be sought. Possibly there is scope for a greater application in North America of a drop-sorter of the Swedish type.

Finally, improvements in the methods of handling stickered packages could increase the attractiveness of automatic sorting for some sawmills. A simple device for realigning misplaced stickers would reduce lumber deterioration caused in handling these packages. The disadvantages of lower kiln performance and increased storage space would still remain.

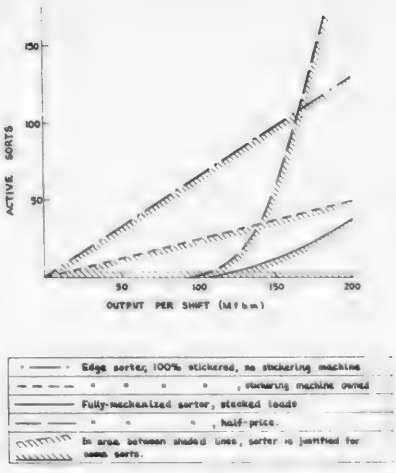


**Fig. 5.—The general characteristics of mill output and sorting requirements are shown where each type of automatic sorter is applicable.**

### Alternatives to Sorters

Many sawmills have too many sorts relative to their volume to justify an automatic sorter, even at substantially lower prices than those now existing. For these, the possibilities through lower-level mechanization of present sorting chains look more attractive. For comparatively low cost, power rolls reduce the pulling time, particularly for long or heavy pieces, and thus reduce labor requirements. Chain breaks with successive speed reductions reduce the peak loading on the operator and allow him to handle more lumber. For sufficiently high lumber volumes, the cost of directing lumber to two parallel chains can be justified by the consequent manpower savings. Any device for realigning stickers (as previously mentioned) would also increase the attractiveness of manual stickering directly at the green chain. There may be scope for increased productivity through the use of motion-study techniques to find the best heights and widths of sorting-chain tables and walkways.

**Table 2.—COSTS AND LABOR REQUIREMENTS ASSUMED FOR MACHINES**

| Partially mechanized sorter | Fully mechanized sorter | Stacker | Stacker and sticking machine |
|---|---|---|---|
| $1,200 per sort | $30,000 + $4,500 per sort | $7,500 | $30,000 |
| 1 man separating green-chain and sorter streams[1] | 1 man separating green-chain and sorter streams[1] | 1 operator[2] | 2 operators[2] |
| 1 man per 100 M fbm to feed sorter | 1 man per 100 M fbm to feed sorter | | |
| 4.5 men per 100 M fbm solid-stacking | 1 man per 100 M fbm patroling, controlling flow to stacker | | |
| 6 men per 100 M fbm stacking and stickering | | | |

[1] If not 100 percent to green-chain or 100 percent to sorter.
[2] Capacity of operator and machine taken as 100 M fbm per shift.

# Drying Stresses in Veneer and Their Relief[1]

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**Veneers free of checks caseharden during drying just as lumber does. Here is an experimental technique by which these stress and strains can be evaluated quickly, easily, and accurately. The experiments showed the stresses can be relieved in a few minutes, provided the conditioning temperature is high enough.**

THE FUNDAMENTALS OF DRYING stresses are known for lumber (5, 6).[2] Such stresses have also been proved to exist in wood veneers. Fleischer (1) showed this when he split 1/8- and 1/4-inch veneer strips parallel to the surface. In the present study the effect of drying conditions and the possibilities of stress relief by heat treatment were examined for 1/8-inch veneer. Such thin sections were chosen instead of boards, not only for experimental advantages, but also because little is known about drying stresses in veneer.

This paper covers residual stresses and shrinkage during drying at —7° to 360° F., the relief of stresses at 240° F. and 370° F., and the temperatures necessary to give substantial stress relief in 0.5 and 0.1 hours at various moisture levels. An illustration of calculated drying stresses is also given. The comprehensive study (3) on which this paper is based provided additional information on the course of drying stress development, the effects of time and storage conditions on the bowing of test slices, relief of stresses at 34° F., 80° F., 160° F., and 320° F., and the stress calculation method.

The Author: Hans Kuebler, a citizen of the Federal Republic of Germany, has a Ph.D. from the University of Hamburg. He has been a wood technologist at the Federal Research Station for Forestry and Forest Products, Reinbek, Germany, since 1951. He worked at the U. S. Forest Products Laboratory, Madison, Wis., as a research associate in 1959.

## Basic Test Method

Small blocks were split from the heartwood of a green 25-inch-diameter log disk of sweetgum *(Liquidambar styraciflua)* at about 8 inches from the pith. From the blocks, samples were flat sawn, planed to a 1/8-inch thickness, and cut to a 3-inch width and 9.5-inch length. To avoid premature drying, the log disk and samples were stored in cold water until drying tests started.

For stress evaluation, test strips were cut as shown in Figure 1. With a microtome knife they were then sliced, parallel to the former sample surface, into four or occasionally eight slices. In the unsplit wood, the surface layers and inside layers, which were internally stressed, held each other in an essentially flat but stressed condition. By slicing and separating the layers, stresses and their corresponding elastic strains were released and slices bowed (Figure 2). The amount of bow was determined by measuring the greatest vertical distance between the inside of the curve and a straight line against which the ends of the slice were held. This distance was called the rise of the bow. When measured against the opposite slice, the distance was designated as double rise (Figure 2). From rise values actual stresses may be calculated (3). Figure 3 gives an example of stresses calculated this way.

Slices cut from internally stressed strips bowed not only instantaneously after slicing, but their bowing increased in succeeding hours and days. Some time later, the slices flattened out when they were stored under warm and humid conditions. In the test series, care was taken to avoid different effects of storage on delayed deformations of the slices.

## Residual Stresses and Shrinkage as a Function of Drying Temperature

**Experiments:** Samples, hanging vertically, were dried at different constant temperatures between —7° F. and 360° F. They were weighed and measured periodically until their weights were about constant. From the dried samples, the first stress test strips were cut 1 inch above their lower edge, sliced, and the rises measured immediately after slicing. The rest of the samples were conditioned for 2 weeks at 80° F. and 30 percent relative humidity. Second stress test strips were then cut and sliced from the lower edge of the sample. All slices were stored at 80° F. and 30 percent relative humidity and remeasured 2 weeks after slicing.

For drying samples at temperatures of 80°F. and higher, an experimental dryer (1) was used. The specimens hung free in the dryer, and the air stream swept downward past them at

[1] Presented by John Lutz of the U. S. Forest Products Laboratory at the 1961 Annual Meeting of FPRS, Louisville, Ky., Session 9, Division 8 (Drying A), June 21, 1961.

This work was done while Dr. Kuebler was a Research Associate at the U. S. Forest Products Laboratory, which is maintained at Madison, Wis., in cooperation with the University of Wisconsin. Dr. Kuebler was there under the auspices of the German Research Council in connection with a Fulbright fellowship.

[2] Numbers in parentheses refer to Literature Cited at the end of this report.



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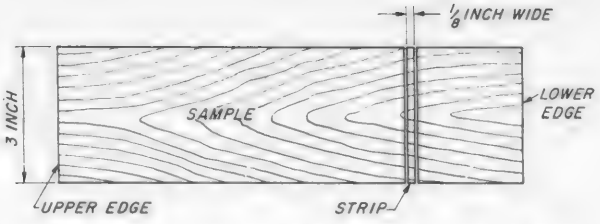


Fig. 1.—Cutting a strip from a 1/8-inch-thick sample for stress evaluation.

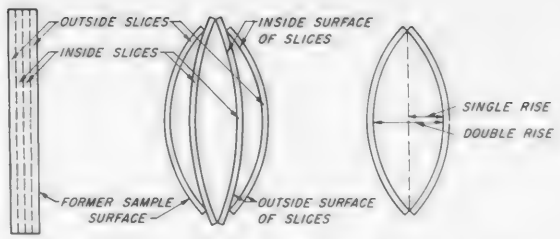


Fig. 2.—A strip and the deformation when it is sliced.

a speed of 800 feet per minute. The air was sucked into the dryer at a temperature of 76° F. to 81° F. and a relative humidity of 12 to 26 percent, corresponding to 0.0023 to 0.0055 pound of moisture per pound of dry air.

The drying at 34° F. and at —7° F. took place in rooms conditioned at 80 percent relative humidity; the 34° F. room was equipped with a blower, but the actual air movement was not much faster than the natural air movement in the —7° F. room. The first slicing and curvature measurement was made in these same rooms.

**Stress Results:** Under these drying conditions, maximum residual stresses resulted with temperatures of 120° F. to 160° F. (Figure 4). Lower temperatures were less favorable for primary sets, which are caused by differential moisture stresses in the first stage of drying. Thus, samples casehardened less at 80° F. and only slightly at 34° F. and —7° F. Even at —7° F., however, some casehardening occurred, though drying lasted several months.

High drying temperatures up to 360° F. undoubtedly caused large primary sets in the first stage of drying because the material was very plastic. In the second stage, after stress reversal, the wood had still considerable plasticity even though already relatively dry. Therefore, the set stresses, resulting from the primary sets, produced secondary sets that more or less canceled the primary sets and diminished the set stresses. There were also secondary sets at drying temperatures below 160° F., but the favorable effect of temperature on the primary sets in the first stage of drying was only partly offset by the secondary sets. Above 160° F., the secondary sets became decisive with increasing drying temperatures and diminished the set stresses considerably; with 360° F., the residual stresses were finally as small as with —7° F. and 34° F.

Figure 4 also shows the delayed deformations of the slices and some stress relief while the casehardened samples were at 80° F. and 30 percent relative humidity. The inside slices behaved qualitatively like the outside slices, yet their curvatures were considerably smaller.

When an end strip was cut from the lowest edge of the sample, the strip curved toward the sample and pinched the saw. The ends of the samples apparently casehardened in width. They dried faster than the central areas and tended to shrink in width. Against the restraint of the central areas, they went into tensile set. This effect diminished as strips were cut farther from the end of the sample and was completely absent 1 inch from the end. End sets of this type cause end waviness of wider veneers (4) and, to some degree, they close end checks developed earlier (2).

**Shrinkage Results:** Thickness (radial) shrinkage from the green condition of equilibrium moisture content in 30 percent relative humidity, as measured in the central portion of the samples, increased with increased drying temperatures above 80° F. (Figure 5). At the samples' corners, thickness shrinkage was about independent of drying temperature, perhaps because increased shrinkage was compensated for by a tensile set in thickness at the edges.

Width (tangential) shrinkage decreased as drying temperatures rose.

Volumetric shrinkage in the centers of the samples increased slightly with increased drying temperatures; high shrinkage in thickness was only partly compensated for by smaller shrinkage in width.

### Stress Relief Investigation

**Experiments:** Flatsawn samples in the usual size were dried in the experimental dryer at an air speed of 800 feet per minute and a temperature of 160° F. until individual weights were about constant. Immediately after drying, rubber sheets 1/32-inch thick

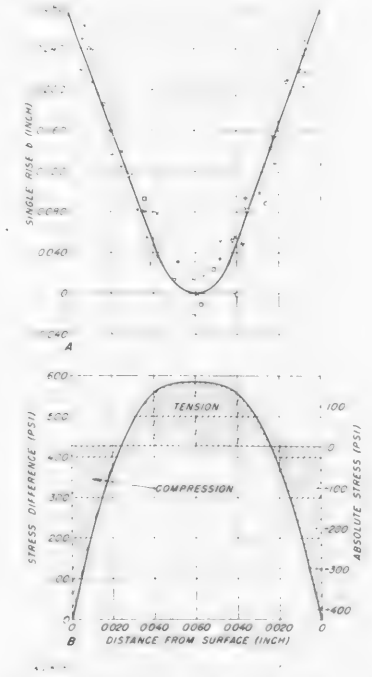


Fig. 3.—Evaluation of stresses in a casehardened sample 1/8-inch-thick and 2.83 inches wide.

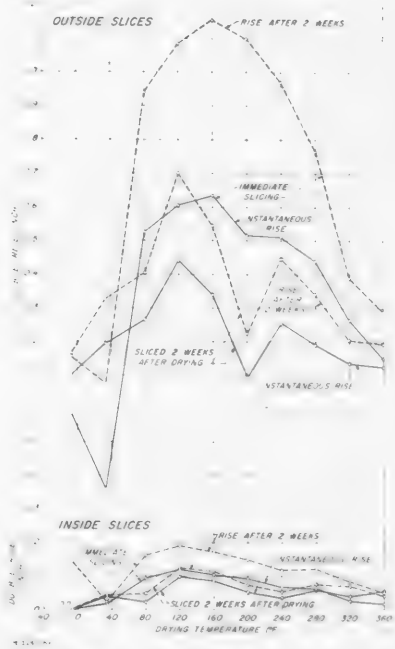


Fig. 4.—Rise of slices as a function of drying temperature.

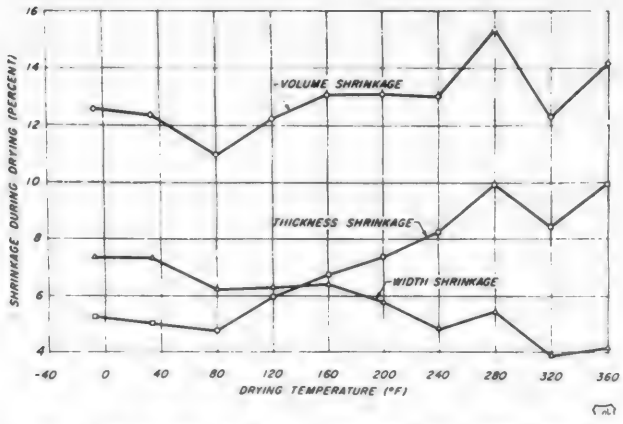


Fig. 5.—Shrinkage, from green condition, of samples at mid-length as function of drying temperature. (Strips conditioned to equilibrium at 80° F. and 30 percent relative humidity after they were dried.)

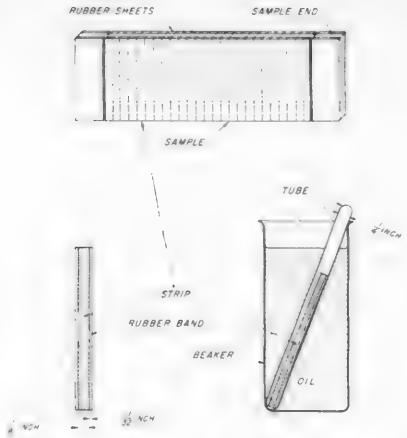


Fig. 6.—Preparation of strips and method of treatment for stress-relief investigation.

were glued on both flat surfaces with rubber cement. Then, after discarding 1-inch-long ends from the lower edges, the rubber-coated samples were cut across their grain (Figure 6) into about 1/8-inch-wide strips. These were stored for several days at 80° F. and a relative humidity of either 30 or 0 percent. By covering the surfaces with rubber sheets, moisture exchange between the wood surface and the atmosphere was excluded so no moisture gradients in the thickness direction or additional stresses could arise after drying. Later, in the stress relief treatment, the rubber sheets had some insulating effect. Heat penetrated into the strips mostly in the grain direction and big temperature gradients in the thickness direction were avoided.

Different strips for stress relief at 160° F. and higher were next exposed for 16 to 24 hours to relative humidities of 0, 30, 65, 80, 90, and 97 percent at 80° F. for moisture conditioning to 0, 6, 12, 16, 19, and 21 percent moisture content, respectively. At relative humidities of 65 percent and higher, considerable stress relief would occur in several days of moisture conditioning; on the other hand, the equilibrium moisture content was not approached for several days. A moisture conditioning time of 16 to 24 hours was considered to be a reasonable compromise, as the moisture content was then nearly the desired value and the stress relief was not too great.

After moisture conditioning, these rubber-covered strips were sealed into glass tubes (Figure 6). Then the strip-containing tubes were inserted into glass beakers filled with oil. The oil temperature was maintained by keeping the beakers in temperature-controlled drying ovens. After specified treatment times, the tubes were taken out, cooled at ordinary summer room temperatures (80° F. to 90° F.), and opened. The strips were then brought into the rooms where they had been moisture conditioned before treatment, the rubber bands pulled away, the cement wiped off the surfaces, and the strips sliced. Handling and slicing the 0 percent moisture content strips was done in the 30 percent relative humidity room. The curvature of the outside slices was measured immediately after slicing, and remeasured after at least several days' storage at 80° F. and 30 per cent relative humidity.

For the treatment temperatures of 34° F. to 80° F., the strips were not sealed in glass tubes but were put directly under the treatment conditions. These included water soaking as well as exposure to different humidities. No moisture conditioning preceded the treatment. In the more humid exposures, the strips picked up moisture and their stress relief was rapid as soon as high moisture content was obtained.

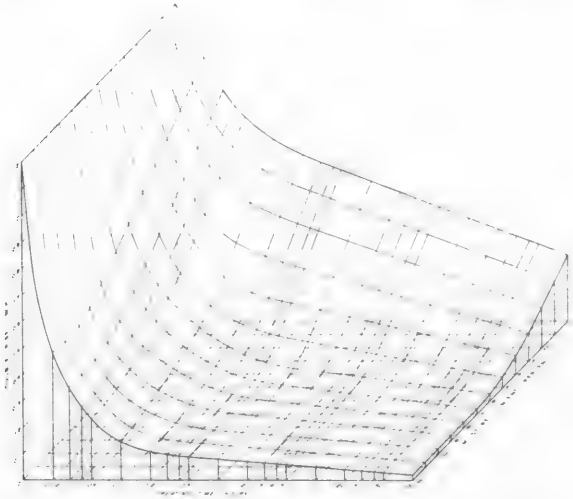

Fig. 7.—Residual double rise of outside slices after treatment at 240° F.

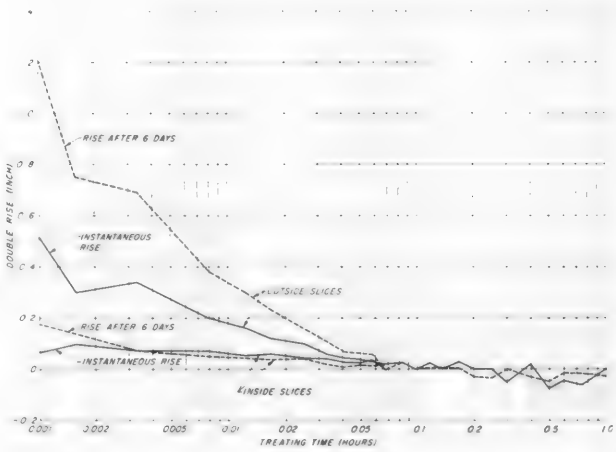


Fig. 8.—Residual double rise of outside slices, after treatment of 370° F. and 0 percent relative humidity.

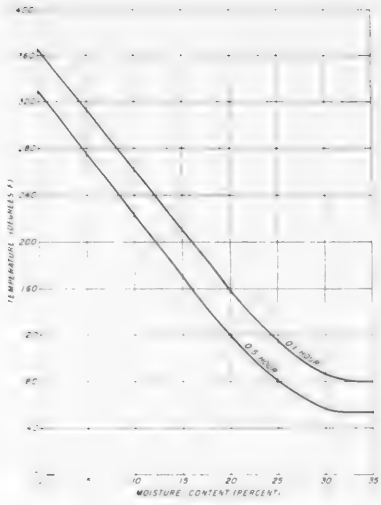


**Fig. 9.—Conditions that relieve nine-tenths of the original stresses within 0.5 and 0.1 hour.**

**Results:** These experiments showed that it is possible to relieve the stresses within a few minutes at different moisture content values, provided the temperature is high enough. For veneer drying, this means the treatment time necessary for stress relief is only a fraction of the total drying time. The results indicate that the usual long stress-relieving times (5) for lumber drying probably can be cut down from several hours and days to less than 1 hour.

Figure 7 shows the results for 240° F. treatment temperature; similar relationships were observed with the other temperatures (3). There was often a linear relationship between double rise and logarithm of treating time (Figure 8). The value in Figures 7 and 8 for the shortest treating times, 0.01 and 0.001 hour respectively, were actually not measured at the named time but at controls without any treatment. When moisture content-temperature conditions are compared with equal stress-relief effects, a linear relationship between temperature and moisture content results (Figure 9).

### Summary

During drying, veneers free of checks caseharden just as does lumber. These veneer stresses and strains are easy to evaluate by measuring the bowing of slices cut parallel to the veneer surface. Compared with investigations on casehardening in lumber, experiments with small veneer sections have several essential advantages: the experiments are much faster to run, more accurate conditions can be applied, and considerably less material is needed.

Under certain conditions maximum residual stresses in the dried veneers resulted with drying temperatures from 120° F. to 160° F., but even at —7° F. and 360° F. some residual stresses were observed. Slices cut from the surface of casehardened veneers bowed instantaneously; their curvature increased in succeeding hours and days. After some time, the slices flattened out, provided they were stored under warm and humid conditions. Boards resawed from casehardened thicker boards should behave similarly. It is to be expected that casehardening and stress relief in veneers have an effect on the properties of veneers and veneer products. By conditioning the veneers, their stresses were relieved in several minutes, provided the temperature was high enough. Dry wood required considerably more heat than moist wood.

In the drying experiments with flat-sawn samples, shrinkage in thickness increased as drying temperatures rose, while shrinkage in width decreased to some degree.

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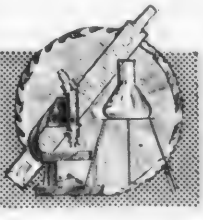
## Abstracting the Literature



### QUALITY CONTROL

**Kumar, Vidya Bushan.** Statistical quality control in the particle-board industry. I. Wood chipper. II. Chip drying. III. Properties of particle boards. Holz Roh- u. Werkstoff 17, no. 11: 440–7 (Nov., 1959); 18, no. 9: 341–3; no. 11: 422–7 (Sept., Nov., 1960). [Ger.; Engl. sum.] *cf.* A.B.I. P.C. 29: p. 858.

Variability and control in three major phases of particle-board mfr. at a highly automated plant are discussed. Even wide variations in wood moisture do not seriously interfere with the control of chip dimensions. Most makes of chippers afford good control and give acceptable chips. However, wet chips interfere with proper control of the drying process; control becomes the better the closer the particles are to the o.d. condition. Among the various props. of the finished prod., water absorption and thickness swelling, as well as bending strength, show the greatest variability and are the most difficult to control; at the same time, their successful control provides the best assurance of uniform particle-board quality. 31 ref.

### DRYING STRESSES

**Schniewind, Arno P.** On the nature of drying stresses in wood. Holzforschung 14, no. 6: 161–8 (Dec., 1960). [Engl.; Ger. sum.]

Drying stresses in wood are classed into three orders, based on the scale on which the stress pattern is repeated, and various subdivisions, depending on the origin of the stress. First-order stresses occur in individual cells as a result of the unequal shrinkage potential of cell-wall layers and because of hydrostatic tension forces in the cell cavity. Second-order stresses are found in tissues, resulting from unequal shrinkage potential of various tissue types. Third-order stresses occur in larger pieces of wood and are due to the moisture gradients devg. during normal drying and to gross variations in shrinkage potential. Hypothetical examples of the three orders are given.

All three influence wood behavior. Potential stresses that would dev. in the absence of creep and relaxation effects are calcd. and found to be large. Relationships between rheological props. and shrinkage in wood are discussed. 34 ref.

## CARBON STRUCTURE

**Leont'ev, E. A., and Luk'yanovich, V. M.** Electron microscope study of the porous structure of activated carbon by means of the replica technique. Izvest. Akad. Nauk S.S.S.R., Otdel. Khim. Nauk no. 11: 1955–61 (Nov., 1960). [Russ.]

The porous structure of 3 activated carbon samples obtained by carbonization of vegetable matls. and wood and activated with carbon dioxide at 950° C. and of activated carbon obtained by carbonization of sucrose was studied by electron microscopy. The prepns. were obtained by the two-stage replica technique described [*cf.* Zhur. Fiz. Khim. 32: 1922 (1958)] which consists of obtaining first an imprint of the surface on collodion from a sample pressure-embedded in PE and then a carbon replica of the collodion surface. The activated carbon samples from vegetable matls. showed the same, typically bidispersed structure: macropores with linear sizes of the order of 1000 A., and a honeycomb of intermediary size pores of the order of 100 A., with frequent breaks in the connecting walls and sometimes absence of walls. The resolving power of the electron microscope (30 A.) did not permit the detection of micropores of the order of $10^{-7}$ cm. Also large macropores ($10^{-4}$-$10^{-3}$ cm.) quite probably remained undetected. Prepns. of activated carbon from sucrose were characd. by the absence of macropores, but showed a honeycomb of nearly spherical intermediary pores, similar to that of the other carbon samples. The possible mechanism of pore formation and the relation of pore sizes (as detd. by microscopy) to the effective sizes detd. by indirect methods (sorption and mercury) are discussed. 17 ref.

## WOOD STRUCTURE (HARDNESS TESTER)

**Sachsse, H. H.** Technique of examining the structure of wood by the needle-puncture method. Holzforschung 14, no. 6: 168–78 (Dec.) 1960). [Ger.; Engl. sum.]

Büsgen was the first to introduce a needle-plunger technique [Z. Forst- u. Jagdwesen 39: 546 (1904)] for detg. the hardness of wood. The same principle was used by Mayer-Wegelin [Holz-Zbl. 77, no. 5: 3941 (1951)] to det. the amt. of summerwood within growth rings by means of "hardness diagrams" and to study the structure of spring- and summerwood. In the hardness tester used, a spiral spring causes a needle to penetrate into the wood sample, and the depth of penetration under a const. specific pressure serves as a measure of wood hardness. After a crit. evaln. of this instr., the present author devd. a different app., in which needles of various diams. are pushed into the sample to a predetd. depth by means of an electromagnetic device, and the elec. measured power required serves as a hardness index. Applns. of the new app. and its advantages over that of Mayer-Wegelin are described. In studies of the phys. props. of wood and their changes, the instr. appeared to give purely objective results. 24 ref.

## DIMENSIONAL STABILITY

**Sadoh, Takesi, Araki, Mikio, and Goto, Teruo.** Studies on the dimensional stabilization of wood. VIII. Hygroscopicity of formaldehyde-treated wood. J. Japan Wood Research Soc. 6, no. 6: 242–6 (Dec., 1960). [Jap.; Engl.sum.] *cf.* A.B.I.P.C. 29: p. 1536; 30: p. 371–3.

Cross sections of hinoki *(Chamaecyparis obtusa)* and birch *(Betula nikoensis)* were trd. with dry hydrogen chloride for 1 hr. and then with formaldehyde at 95 C. for 7 hr. Hygroscopicity detns. showed that the trmt. effectively stabilized wood against dimensional changes. Sorption isothems at 22 indicated that the equil. moisture contents of the trd. woods were lower than of the untrd. woods at all R.H. values. The trmt. reduced the sorptive surface by 44–49%, but did not change the distribution of sorptive energy within the wood, as shown by unchanged isosteric differential heats of sorption plotted as a function of R.H. Hence the mechanism of dimensional stabilization by formaldehyde seems to involve a uniform decrease of sorptive energy, rather than a crosslinking between sorption sites. 7 ref.

## MOISTURE VARIATIONS

**Tsoumis, George.** Investigations on variations in the moisture content of air-dry wood. Holz Roh- u. Werkstoff 18, no. 11: 415–22 (Nov., 1960). [Ger.; Engl. sum.]

Moisture variations in a.d. (seasoned) wood exposed to varying climatic conditions under shelter were not essentially different for different sp. (beech, oak, chestnut, and pine) or for different sample dimensions (1 × 10 × 25, 2.5 × 10 × 25, and 5 × 5 × 25 cm.). The greatest variation in any specimen within a given month was 4.4%; the max. deviation between av. values in samples of the same sp. and size was only 2.3%. Wood sp. and sample size had statist. significant effects on monthly values, but not consistently the same in all four months observed. Neither the sp. gr. of the wood nor the position of annual rings had statist. significant effects. Monthly, weekly, daily, and hourly variations in moisture content ranged from zero to 2.7, 3.1, 1.1, and 0.9%, resp. Yearly changes ranged from 3.4 to 6.3% and were significantly influenced wood sp., sample size, and growth-ring position, but not by sp. gr. A direct linear relationship was observed between measured moisture contents and equil. values calcd. from temp. and R.H. detns. in the immediate proximity of the samples; differences between observed and calcd. values became greater and statist. significant when the calcns. were based on weather data taken at some distance from the stored samples. 26 ref.

## PARTICLE BOARD

**Street, Howard H.** "Let's solve our problems." Southern Pulp Paper Mfr. 23, no. 9: 100, 102-4 (Sept., 1960).

America's high-cost ind. facility, striving to compete in this period of world devt., represents a liability to our nation. If we fail to stabilize a spiraling cost structure today, we will face a crisis tomorrow. We are in the throes of a social revolution. There is no power or force which can be

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*BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY*, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry.

quickly applied to halt this convulsion. It will only come into equil. through creative contributions, devg. a balance within the economy. The responsibility of the managers of ind. is to make appln. of technol. devts. If we have the courage to employ these things to reduce costs, we will be guaranteeing the security of the ind. and that of the nation.

**Iwashita, Mutsumi, Matsuda, Toshiyo, and Ishihara, Shigeharu.** Studies on particle board. III. Studies of hot pressing. 1. Effect of curing conditions, especially moisture content of wood particles. Bull. Govt. Forest Expt. Sta. (Japan) no. 126: 63–89 (Nov., 1960). [Jap.; Engl. sum.] *cf.* A.B.I.P.C. 31: abstr. 945.

Data on the effects of varying hot-press conditions (duration, pressure, particle moisture, etc.) on the mech. props. of particle boards from *Pinus densiflora* indicated that moisture contents of 20–25% in surface particles and of 10% in core particles are the most desirable for long curing cycles, but that lower moisture contents are required for shorter press cycles 13 ref.

## BARK UTILIZATION

**Murata, Tokitsu, and Takamura, Norio.** The utilization of bark as raw material for fiberboard. I. The influence of bark on qualities of hardboard. Bull. Govt. Forest Expt. Sta. (Japan) no. 126: 35–50 (Nov., 1960). [Jap.; Engl. sum.]

Asplund pulps (4 min. steaming plus 1 min. defibration at 10 kg./sq. cm. steam pressure) were prepd. sep. from the wood and the bark of several sp. and from mixts. contg. 10, 30, or 50% bark. The course fibers were refined in a Sprout Waldron lab. refiner and formed into hardboards 1/8 in. thick by the wet process (but without sizing) and by pressing at 180° C. The woods examd. included red pine *(Pinus densiflora)*, cedar *(Cryptomeria japonica)*, cypress *(Chamaecyparis obtusa)*, fir *(Abies firma)*, larch *(Larix kaempferi)*, spruce *(Picea excelsa)*, beech *(Fagus crenata)*, poplar *(Populus maximowiczii)*, birch *(Betula maximowiczii)*, and linden *(Tilia japonica)*. Pulp yields decreased with increasing bark content, but since 70–90% of the bark remained in the pulp, the use of unbarked wood offered a possibility of increased raw-matl. utilization. Power consumption decreased (moreso in refining than in defibration) with increasing bark proportion, esp. for softwoods. Although stock freeness decreased with increasing addns. of bark, no sheet-forming troubles were encountered with mixts. contg. up to 30% bark, except for fir and spruce. Pulps of 100% bark fiber could not be pressed satisfactorily because of dewatering troubles and sticking of fibers to the caul plate and back screen in the hot press, except with cypress, fir, and linden. Bark-contg. boards were darker than bark-free boards and had a lower sp. gr. despite the reduced pulp freeness, perhaps because of impaired interfiber bonding. Modulus of rupture in bending and sp. bending strength (corrected to a d. of 1.0) decreased with increasing bark proportion, except in linden, where even 50% of bark did not impair the strength contributed by the strong phloem fibers. The water repellency (sizing effect) dropped with higher bark contents in all softwood boards, except pine and larch, but increased slightly in all hardwood boards. Board from red pine bark (but from no other sp.) showed a very high sizing effect; the water absorption of a 50:50 bark and wood mixt. was only half that of a board made of 100% wood pulp. This effect was shown to be due to the presence of ether-sol. extvs., largely waxes, in pine bark. 11 ref.


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A FIRST-HAND REPORT ON

# The Latin American Forestry Institute

R. N. JORGENSEN
Pennsylvania State University,
University Park, Pa.

**Three years in Venezuela have convinced Author Jorgensen that Latin American countries are striving to do a good job in forestry—but they need help. He suggests North American students could give this help while they study "free" in one of the most interesting spots in the world.**

LATIN AMERICAN FORESTRY INSTITUTE, School of Forestry, and School of Engineering, Universidad de los Andes, Merida, Venezuela.

THE LATIN AMERICAN FORESTRY INSTITUTE had its conception in 1951 in Rome, Italy. The government of Venezuela offered to the Food and Agriculture Organization of the United Nations the School of Forestry at the University of the Andes, in Merida, as a seat for the Institute. Considerable time was involved to establish financial arrangements through the cooperating countries of the Latin American Forestry Commission, the FAO, and the host country. In August, 1956, the first director Dr. Antonio J. Uzcategui Burguera, was appointed and a technical advisor, Dr. E. J. Schreuder of Holland and the FAO, reported at the Institute.

The first 2 years of the Institute were probationary, with a specialist in Silviculture and Ecology and one in Wood Technology and Utilization stationed at the Institute as a portion of the FAO effort. These two men, the technical advisor and the director, in cooperation with the faculty of the Forestry School, were to formulate plans for research and instruction done during the probationary period and build a foundation for the future work to be accomplished. In 1958, when more financial support had been obtained from the members of the Latin American Forestry Commission and other interested countries, particularly France, England, and Holland, had contributed funds on the basis of the advancements made in the first 2 years, the Institute was placed on a permanent basis with the provision that the FAO support in the form of personnel and limited funds would continue for another year.

In 1959, the Institute was considered by all those concerned as an established organization, and the FAO personnel were separated. The reporter is not familiar with all the details, but most of the FAO financial support was also withdrawn at this time. The Institute is supported by contributions from interested countries within and without the Latin American Forestry Commission, and the host country, Venezuela, assumes a major part of this support. The Institute operates today under the control of a Governing Body which is part of the Latin American Forestry Commission with the Resident Director in charge. Operation of the Institute is similar to many of those set up in the United States, where the physical plant has been supplied by the local school and the faculty personnel are utilized on a part-time basis, to supervise various research projects and instruction that make up the Institute program.

The physical plant of the Faculty of Forest Sciences at the University of the Andes is an outstanding contribution. The laboratories, equipment, offices, library, and field experiment stations contain only the most modern equipment in more than sufficient quantity, and additions are made

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[1] A contributed paper solicited by International Editor, R. W. Wellwood. Approved for publication May, 1961.



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quickly to remedy any considered deficit. To clarify the scope of the work which can be done at the Institute, one may say that the fields of the existing faculty of the School encompass all those usually included in Forest and Wood Sciences. There are 16 regular staff members of the several professorial ranks; 9 of professorial rank in related schools such as engineering, chemistry, and economics who teach foresters on a part-time basis and are considered part of the staff, and 10 technicians and specialists who handle such things as photographic work, chemical analyses, and soil tests. This is comparable to many accredited forestry schools in the United States.

With the Institute located at the site of such a fine school, some discussion of the Latin American system of education is necessary to explain why the title of the Institute contains the word "Training." At the present time, all institutions of higher education in the Latin American area offer a single terminal degree for the course studied, although the courses studied may be 4, 5, or 6 years in length, depending on the subject. Any person who obtains such a terminal degree is addressed by the title of "Doctor"; there is no provision for, or titles suggested for, any advanced study as the master's and doctor's levels in the United States. Corollary to this situation is the fact that the great amount of research accomplished under the master's and doctor's degree system is lacking where these degree systems do not exist. With this in mind, part of the Institute plan was to offer advanced study work beyond the terminal degree and award some certificate of recognition for such research. In time it was hoped that the Institute might be a leader in developing a program of advanced degree work and associated research in the Latin American area.

From 1957 to 1959, the reporter served as FAO Forestry Officer in Wood Technology at the Latin American Forestry Institute. During these 2 years the prospective program of the Institute in all fields was developed by the cooperating faculty, the Director, the FAO personnel, and was approved by the Latin American Forestry Commission and the Governing Body. Six Institute Bulletins were published during this time and distributed internationally, and about 12 special project reports were made to the Commission and cooperating countries or government agencies. Three fellowships were granted by the Institute during this time and advanced studies carried out in silviculture, pulp and paper, and wood technology by graduates from Venezuela. In addition, Holland sent two graduate scholarship men to study in the fields of silviculture and wood technology.

One of the basic projects in wood science was to compile a file of more than 400 species from the Latin American area with their appended references indicating that some work had been done on the physical and mechanical properties of these woods. These tests had been made all over the world during the past 50 years, and this was the first time the information had been gathered together. The assembled file prevented duplication of research effort and provided a steppingstone for future work. When it is considered that an expert botanist in the field has estimated that there are as many as 12,000 species of trees in the Latin American area, it can be seen from the small number in this file that there is much basic work to be done in the field of wood science. Uses of wood in the tropical areas are considerably different from those in the temperate zones, primarily because of decay and insect problems, and studies in wood preservation were inaugurated in the new experimental treating cylinder built by the School of Forestry during the first part of the Institute's life. The School was already equipped with a fine dry kiln, and plans were made to continue drying studies of those woods presently considered commercially important. Due to the heterogeneous forests of Latin America, probably one of the most sought after methods of utilization is in the pulp or particle forms. The School of Forestry was completing in 1959 a most modern and complete pulp and paper laboratory, and it is expected that much valuable information will come from this facility. Anatomical studies and identification of the large wood collection at the School will be continued to correlate such information with the results of other studies. This tropical wood collection is unique in that it is 100 percent vouched by herbarium material, some of which still presents problems to the botanists who attempt to classify the collection. In summary, the School of Forestry facilities are virtually complete for all studies in Wood Science, and the program of the Institute was planned to utilize all of these as rapidly as possible, depending on staff available.

In the field of Forest Science, probably the most important work during the first years of the Institute was a remapping of the vegetation of Venezuela. Until this time, the maps to date had been considered adequate, but subsequent observations by air had indicated serious discrepancies. Excellent cooperation by many persons in the Ministry of Agriculture and by the Armed Forces in the use of helicopters as well as the local staff permitted this remapping to be done in the first 3 years. In coordination with the mapping, several ecological studies were begun on some of the many forest types existing in the country and continent. Studies on growth measurements, germination, inventory methods, and introduction of exotic conifers were reported upon in early publications and the projects continued. The detrimental effects of migratory agriculture on forest economics was reported to the Commission at an early date, and studies continue in an effort to solve this most important socio-economic and legal problem.

The vast number of uninvestigated species of the area, both from the aspect of Forest Science and Wood Science, are sufficient to re-emphasize a situation which the writer feels should be made very clear. This is the fact that Latin America in general is striving greatly to do a good job in forestry but is still in the infant stages, often lacking manpower to establish a complete organization, faced with problems for which there are no prototype solutions, and dealing with material both in original and final form which occupies a completely different economic status in the public eye than it does in the United States. They are doing as well as the United States did at the same evolutionary point (40 years ago). They need all the assistance they can obtain, however, and in almost all cases, they will be most receptive.

Much of such assistance could be provided by students who are interested in the area and who would be willing to do a year or two of graduate study at the Latin American Forestry Institute under the guidance of competent professors. No formal advanced degree could be conferred, but the writer would urge prospective employers to recognize such work and schools in this country to consider acceptance of reports and theses done at the Institute as a large part of advanced degree requirements. At present, the operating funds of the Institute are limited, and scholarships are restricted to natives of South America. These are subsistance scholarships, however, and so far as the writer knows, there are still no direct charges for study at the Institute. If you can get there, live and eat, then you can study free at one of the most interesting places in the world. There are vast amounts of knowledge to get and to give, and the writer hopes this small report may stimulate such exchange.

# Abstracts of Selected Papers Presented at 15th Annual Meeting

Woodfin

Landt

### Effect of Resaws on Production and Performance of Circular Headrig Sawmills

E. F. LANDT and R. O. WOODFIN, JR.
Rocky Mountain Forest and Range Experiment Station, Rapid City, South Dakota

A study of four circular headrig sawmills in the Black Hills of South Dakota and Wyoming revealed that the installation of resaws behind the circular headsaw increased sawmill efficiency both in rate of lumber production and in volume of lumber cut from small ponderosa pine logs. Included in the study were circular headrig mills with horizontal band resaw, cant sash gang resaw, and vertical circular resaw. Results showed that the horizontal band resaw mill excelled in lumber production rate; whereas, the gang resaw mill excelled in sawing accuracy. The sawing speed (delay time not included) of the horizontal band resaw mill was about three times faster than the circular mill with no resaw. The cant sash gang resaw mill was about two times faster than the mill with no resaw. Actual production rate (delay time included) per man-day for both the band and gang resaw mills, however, was increased only about 1.4 times. Lumber volume recovered from logs with identical scale was, on the average, 8 percent greater at the horizontal band resaw and at the cant sash gang resaw mills than at the circular mill with no resaw or the vertical circular resaw mill. The band and gang resaw mills have thinner saws and usually cut thinner slabs than the circular mill with no resaw or the verticle circular resaw mill. Sawing practices in cutting 4/4 boards at the resaw mills were similar to the practices used at the circular headrig mill with no resaw. Little difference, therefore, in lumber grade was expected. Scarcity of upper grades of lumber in the small logs, plus the practice of using circular headrigs to cut cants for resawing, further ruled out any possible differences that might otherwise exist between the headrigs in this regard.

### Particle Board—From a Consumer's Viewpoint

T. W. NOBLE
Decar Plastic Corp., Middleton, Wis.

Considerations of a consumer's requirements and end-use in a planned program of product development, customer service, and sales development and expansion are discussed. This new and novel app oach to the particle board problem (over production and/or under consumption) presumes that products, such as particle board, can be engineered to have certain physical properties, or a combination of physical properties, particularly designed to a particle end-use or a particular customer requirement. This approach vividly contrasts with the present dedication of the particle board industry to maximum production, maximum yield, minimal physical properties, price-cutting (often without regard to costs), in the probably hopeful expectancy that such an ill-directed program will ultimately result in sufficient volume to result in a profitable venture.

Recommendation is made to seriously consider investigating the possibility of developing specific types of particle boards, having specific physical properties for particular end-uses and applications, such that a specialized market will justify a price structure and profit margin that will justify a continuance of such a development program. A specialist has certain inherent advantages that accrue to a specialist.

Pentoney

Davidson

### Rheology and the Study of Wood

R. E. PENTONEY and R. W. DAVIDSON
State University College of Forestry, Syracuse, N. Y.

Rheology is defined, and its relationship to theories of elasticity and flow of materials is discussed. Certain cases are described where progress made in understanding the mechanical behavior of materials has been the result of rheological studies. Phenomenological rheology is presented in terms of experimental methods used, the major independent variables, and the use of mechanical, electrical, and mathematical analogues. The advantages and limitations of this approach are outlined. The theoretical approach to the mechanical behavior of high polymers based on considerations of molecular structure and configuration, as well as extension of elasticity theory to include large strains is briefly summarized. The rheology of wood is introduced by presenting the current status of knowledge in this field and the experimental methods employed. Suggestions a·e offered for future work on the mechanical behavior of wood.

### Present and Future Markets for Wooden Pallet Products

W. H. SARDO, JR.
National Wood Pallet Manufacturers Assn., Washington, D. C.

The wooden pallet is used to speed the flow of goods and to reduce the cost of handling in warehousing, manufacturing, and transportation operations. Great savings in handling and labor costs accomplished by palletization has created a desire on the part of industry to employ pallets wherever possible. Today in the U.S., and many parts of the world, the "throughout concept" of palletization is fast becoming a reality.

At least two independent management consultant firms have classified the wooden pallet industry as the only growth segment of the lumber and wood products industry today. In 1949, only 20,000,000 wooden pallets were sold in this country, but 62,308,000 were sold in 1960, a new record. Today, the wooden pallet accounts for a little more than 98 percent of the permanent pallets sold in the U.S., while substitutes account for less than 2 percent of the total. Five years ago, only 50 percent of the expendable pallets produced were of wood while today more than 80 percent are wood. This industry represents one market where wood's share of the pie is becoming larger rather than smaller.

Sardo

Camarano

### Marketing of Lumber and Forest Products to the Government

A. M. CAMARANO
National Lumber Manufacturers Assn., Washington D. C.

The United States Government is the world's largest buyer of goods and services. It exercises a great deal of influence on lumber markets and indications are that this influence will be sharply accelerated in the months and years ahead. The Federal Government spent more than $1 billion on military construction alone last year and another $15 billion to construct office buildings, post offices, research centers, schools, hospitals and the interstate highway system. All of these represent direct cash outlays and therefore have a direct relationship to lumber markets. The Government influences lumber markets to a much greater extent indirectly and in ways that oftentimes go unnoticed: through its loans, grants and mortgage insurance programs as in the case of the Urban Renewal Program, College Housing Loan Program, and the Federal Housing Administration and Veterans Administration mortgage insurance programs. When combined, the total Government influence on construction would conservatively approximate some $50 billion. Lumber markets will be affected and also offer possibilities to those interested in the marketing of lumber and forest products to the Government. However, in order to participate in these programs, suppliers and manufacturers must understand some basic concepts about how the Government does business. They must know how to seek out business opportunities that may be of interest and acquaint themselves with the programs offering the biggest opportunities for participation now and in the months ahead. This paper directs attention to how the Government buys, the major agencies doing the buying, and Government programs which will offer opportunities to those interested in the marketing of lumber and forest products to the Government.

## NAMES in the NEWS

**Ted A. Owens,** Harriman, Tenn., a senior majoring in pulp and paper technology at North Carolina State College, has been named recipient of the J. Spencer Love Fellowship for study at Harvard University.

Appointment of **Fred Dolton** as manager of national account sales for the "Michigan" line of construction machinery is announced by A. E. York, sales manager, Construction Machinery Division of Clark Equipment Company, Benton Harbor, Mich.

**George C. Romeiser** has been appointed secretary-manager of the Southern Hardwood Producers, Inc., it was announced by H. S. Mersereau of the Crossett Lumber Company, Crossett, Ark., president of SHPI. He succeeds **L. J. Heatherly,** who is retiring after 25 years service.

**James L. Miller** of the Owatonna Tool Company, Owatonna, Minn., has been made District Manager of Oklahoma and Arkansas. Mr. Miller resides in Tulsa, Okla.

Dr. Hardy L. Shirley, dean of the State University College of Forestry, Syracuse University, announced that **Harry M. Gray,** president, Empire State Paper Research Associate Inc., and vice president and director of manufacturing, Sealright-Oswego Falls Corp., Fulton, N.Y., has been appointed to the faculty as Adjunct Professor, Pulp and Paper Technology. The new appointment comes in recognition of Gray's many years of contributions and distinguished service to the college and the pulp and paper profession.

**Len Moyer** has been appointed assistant to the general manager of Vancouver Plywood Co., Portland, Oregon. He has been with Vanply for over a year; for the previous 10 years he was sales manager for the Murphy Lumber Co.

**Dr. Nicholas V. Poletika,** vice president of research for the Union Lumber Company, Ft. Bragg, was elected president of the Technical Advisory Council to the University of California's Forest Products Laboratory. He succeeds Dr. Howard S. Gardner.

Terminating 37 years of trade association management, **Ormie C. Lance** retired from his position as secretary-manager of the National Woodwork Manufacturers Association June 30. His successor is **James E. Nolan,** who has been Mr. Lance's assistant for the past 11 years.

The election of **Howard W. Morgan, George H. Weyerhaeuser,** and **J. E. Nolan** as executive vice presidents of Weyerhaeuser Company, Tacoma, Wash., was announced by Norton Clapp, president. The designation of three executive vice presidents by the board of directors "is in recognition of the increasing responsibility they share for the progress and success of the company," Clapp said.

**Donald H. Gott,** newly appointed secretary-manager of the American Walnut Manufacturers Association, has taken over direction of the association's offices in the American Furniture Mart, Chicago. Mr. Gott formerly was sales manager for the Marshfield (Wis.) mill of Weyerhaeuser Company's Roddis Division.

## EMPLOYMENT *Opportunities*

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### Positions Offered

E–420—Wood technologist, preferably with M.S. and some industrial experience, wanted for position in applied research on wood utilization. Chemical background and experience in wood finishing or lumber drying helpful. Complete resumé needed. (June and July)

E–421.—Position available for an aggressive young sales engineer to develop Canadian markets for structural laminated wood products. Background in lumber manufacture and building design desirable but not essential. Send resume stating all particulars. (June–July)

E–422—Want young man for quality control work on laminated wood products, either a 1960 or 1961 graduate. Prefer man with southern background, because position is in south central U.S. Man selected will spend 4 to 6 months in our western area before being assigned to a southern mill. Little or no travel required. (July)

E–423—Utilization-minded state forestry agency invites inquiry from qualified, wood products-utilization specialist interested in post-retirement position. Challenging activities in all phases of wood utilization, counsel to industry, industrial development assistance, and product and process improvement work. Moderate travel required; pleasant climate; adequate compensation. (July–Aug.)

E–425—Woodwork production engineer wanted to act as methods and liaison man within the wood-working facility. Must work with wood laboratory of the engineering division and by assignment assist vendors plants under the direction of the purchasing department. More than average knowledge of finishing processes and procedures with good overall working knowledge of cabinet work and mill functions. Experience and some college training necessary for designing and preplanning new products and finishings. Very good security ad benefits. Submit resumé. (July–Aug.)

E–426—Want aggressive man (28–40) with B. S. or M. S. in wood technology at least 3 to 5 years experience in development work, preferably in flush door and plywood products, for large midwest company's Product Development Department. Experience and knowledge needed in hardboard, particleboard, plastics, adhesives, finishes, etc. Ability to bring product development projects to a conclusion essential. Salary range $7,500–$9,500. (July–Aug.)

### Employment Wanted

631—Wood technologist in composition board field, 7 years in quality control, and product development and supervision. Prefer western U.S. Married, age 33. (July)

642—Executive available; experience in case goods, setting up plant operations, supervision, quality control, and purchasing. Desires challenging position with progressive company, can produce results, age 28. (June and July)

643—Wood technologist with M.S. available at end of June. Position desired either in the research of glue products, papermaking, or international business.

644—B.S. in wood technology (U. of Mich.) desires sales, technical sales, promotion work, public relations, management (in this order) in marketing aspects of forest products. (July–Aug.)

645—Young man, 28 years old, married, children, graduating from Michigan State with B. S. in wood technology in Sept. 1961. Interested in research, production, management, and control. Prefers Midwest, South, West Coast. (July–Aug.)

646—Want position in wood products industry. Has M.S.F. in wood technology, experience in wood preservation, exterior wood coatings and wood-moisture relations, but would accept position in other sections of wood industry. Bilingual (French and English). Location preferred in the province of Quebec, Canada. (July–Aug.)

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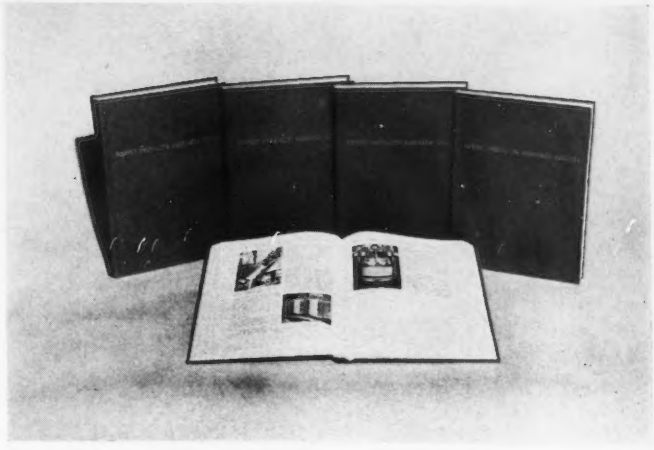

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**1948—Vol. II—UTILIZATION, FIBER PRODUCTS, BARKING, FINISHES, MACHINERY, R. F. HEATING. 50 papers, 500 pp.**

Articles cover: economics of wood-waste utilization; losses in Redwood logging; small log gang sawmill; utilization of low-grade hardwood lumber; wood-distillation industry; sawdust carbonization; animal feeds from wood residue; small wood briquetting machine; special machines for utilization of waste slabs for glued core stock; interior trim from wood waste; wood-fiber production with revolving disk mills; effect of some manufacturing variables on the properties of fiberboard prepared from milled Douglas-Fir; small hydraulic log barker; mechanical methods of bark removal; studies on the chemical composition of bark and its utilization for structural boards; research in industry laboratories; history of furniture finishes; finishes resistant to alcohols and acids; low-bake synthetic finishes; simple testing methods for finishers; planning floor space for woodworking equipment; maintenance and operating practice for tungsten carbide tools.

**1949—Vol. III—RAW MATERIAL, FURNITURE, PLYWOOD, UTILIZATION, GLUES, SEASONING. 55 papers, 607 pp.**

Articles cover: more wood per acre; integrated wood utilization at Crossett; harvesting sawlogs; portable wood chippers; wood fibers from veneer waste; small permanent-type sawmills in better forest utilizatiton; pulpwood handling in the Lake States; tropical wood research for the furniture industry; effect of plywood glue lines on the accuracy of moisture-meter indications; No. 3 common Northern hardwood lumber for mechanized processing into glued products; cut stock from western softwoods; assembly material in furniture manufacture; supplementing wood with metal in furniture manufacturing; extending hot press urea resin with wheat and rye flour; furniture finishes; lumber core panels; rotary veneer cutting; molding plywood; insert-point circular headsaws; ills besetting the furniture industry; utilization of Redwood bark; utilization of waste sulfite liquor in concrete; semichemical pulping; dry-formed boards bonded with resins; wood, plywood and hardboard; compreg-resin-treated densified wood; wood preservatives; wood boring beetles; ignition temperatures of fireproofed wood, untreated sound wood, and untreated decayed wood; wood waste disposal and air pollution control in the Los Angeles area; pulp mill pollution; chemical composition of Ponderosa and Sugar Pine barks; lumber recovery from Douglas-Fir logs in British Columbia; resin adhesives; development of working stresses for stress-grade lumber; design and performance of laminated wood trusses, glued laminated wood, glued laminated Wej-weld frames; radio frequency heating.

**1950—Vol. IV—MILLING, CONTAINERS, QUALITY CONTROL, PLYWOOD. 45 papers, 506 pp.**

Articles cover: quality of second growth Douglas Fir; grading problems; quality control and the improved seasoning processes of the Redwood industry; saw teeth in action; lumber research to meet modern competition; hardwood log grading; recent developments in wirebound containers; method of utilizing and fabricating waste lumber; tests of strapped and lightweight lettuce crates; recent developments in containers; papermaking fibrous raw materials; utilization of low-grade hardwoods and softwoods; relation between wood and pulp properties; power vs. hand falling and bucking in logging operations; handling pulpwood; quality control in sawmill operations; hardwood plywood quality control; quality control in furniture production; defect detection equpiment non-destructive testing.

**1951—Vol. V—MILLING, MACHINING, PRESERVATION, UTILIZATION, GLUES, KILN DRYING. 51 papers, 400 pp.**

Articles cover: circular sawmills in the Tennessee Valley region; quality control in lumber manufacture, gangsaws in the manufacture of southern pine lumber; tropical hardwood production, logging and military equipment availability; defense and the availability of woodworking equipment; the importance of wood in the mobilization program; mobilization requirements for technical men in the woodworking industry; lumber conservation in military procurement and container design; military requirements for wood in packaging; wood requirements for specialized military uses; the place of small business in the military procurement program; marine laminating; selecting White Oak for bending lumber; machinability studies; carbide cutting tools in the wood industry; carbides; fire retardant treated lumber; wood preservation with particular reference to creosote; what the furniture industry expects from college-trained men; the scope and objectives of college training; graduate training in forest products technology.

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